

FATIGUE SYMPOSIUM PROCEEDINGS

NOVEMBER 1-2, 1995



NATIONAL TRANSPORTATION SAFETY BOARD

AND

NASA AMES RESEARCH CENTER



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Acknowledgements



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Dear Participant:

Congratulations! On November 1 & 2, 1995 you made a difference in transportation safety. By attending the first-ever multimodal symposium focusing on fatigue in transportation, you acknowledged the need for information on this subject and demonstrated your willingness to do something about it.

For nearly a quarter of a century, the NTSB has been addressing the problem of fatigue in transportation. During that time, we have made nearly 80 recommendations to operators and regulators in all modes of transportation. They have ranged from asking for additional research to specific regulatory changes. They have also focused on the need for educational programs, such as the one you attended, aimed at helping the transportation community better understand the debilitating effects of this fatigue and to present some measures that can be implemented now to combat the problem. In effort to "put our money where our mouth is" we decided to sponsor a pilot symposium. Needless to say, we believe that the logic of our recommendations was validated by the response we received.



Representing every mode of transportation, nearly 600 people from 16 countries attended the symposium. What made this event unique is that management, labor, academia and government all worked and learned together.

This was a great first step, but it was also perhaps the easiest one. We must now all continue to work together to make meaningful changes to the infrastructure on which the operational practices of the transportation system are built. This will be difficult but worth the effort.

In the meantime, we feel that the education and training module presented by Dr. Mark Rosekind as well as the presentations by Drs. Dinges, Dement, Czeisler, Pack and Roth will serve as prime examples of how we can begin to combat the problem now. The Safety Board will continue to urge the modal administrations within the Department of Transportation to sponsor similar programs. We hope that with what you learned at the symposium, you can take a leadership role in this growing national effort.

Jim Hall
Chairman

Dear Participant:

On behalf of NASA and the Fatigue Countermeasures Program, I add our congratulations and thanks for your participation in the highly successful multimodal symposium on "Managing Fatigue in Transportation." This unique forum provided an opportunity for diverse groups to address the issue of fatigue from a variety of approaches.

We applaud Chairman Hall and the NTSB for their leadership and continued activities to raise the visibility of this issue and provide constructive recommendations.

An important theme expressed throughout the symposium was that there is no magic bullet to eliminate human fatigue in transportation operations. This places the responsibility on all components and members of the transportation industry to address fatigue, and whenever possible, make improvements. Every participant is encouraged to take some action to educate, address a scheduling issue, use a countermeasure or apply some piece of knowledge acquired at the symposium. Any activity that will reduce the adverse effects of fatigue and promote performance and alertness will be another incremental step forward. It was clear that with some creativity, action, cooperation, and tenacity, we can make a difference in this area. The ultimate goal must always be kept in sight: to improve transportation safety.



Mark R. Rosekind, Ph.D.
Chief, Aviation Operations Branch
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OPENING REMARKS BY

JULIE BEAL

**DIRECTOR OF PUBLIC AFFAIRS
NATIONAL TRANSPORTATION SAFETY BOARD**

November 1, 1995



Good morning. Welcome to this very special symposium on fatigue in transportation. It is particularly good to greet you – the people who are in the best position to identify and possibly prevent the deadly effects of fatigue on transportation safety.

First let me tell you who you are. You are pilots, air traffic controllers, flight attendants, mechanics, railroad engineers, conductors, truckdrivers, pipeline operators, riverboat pilots, marine captains and mates. You represent unions, management, academia, government and political action groups. You are from 16 countries from around the world and you all sit here together today as one industry prepared to work toward a common goal – safety. I congratulate you for that.

We have a great deal of work to do over the next two days. Today we will learn from some of this country's premiere authorities about fatigue and its effects on the human body. More importantly, we will learn how this knowledge can be applied to improve operator sleep, alertness and performance. Tomorrow we will break out into modal groups to discuss how this information can be incorporated into your specific operational environment. We recognize that you will not leave with all of the so-

lutions, but perhaps collectively we can move a step or two closer to combating this safety problem.

You have plenty of reading material. NASA studies and NTSB reports and recommendations are provided to help you better understand our perspective on the issues surrounding fatigue. Also there is a fatigue resource directory that Dr. Rosekind will describe in detail later today and a list of participants.

Over the past year, I've had the pleasure of working with Dr. Mark Rosekind from the NASA Ames Research Center in putting together today's symposium. His professionalism and expertise in the area of fatigue have left me with no doubt that you are in good hands today. I am sure that you too will be impressed by the information offered by the educational program developed under his leadership at NASA.

Thanks also to NTSB Chairman Jim Hall for his insights and for having the conviction to sponsor this event. Through this symposium the Chairman advances the spirit of the recommendations the Safety Board makes to others. He should be commended for his leadership in putting together his educational opportunity.

Jim came to the Board two years ago and has served as Chairman since October, 1994. Since his term began Jim has been to the scene of ten major accidents including the fatal aviation accidents at Roselawn, Indiana; Pittsburgh, Pennsylvania, and Raleigh Durham, North Carolina. He has also been to several surface accidents including the Ringling Brothers Circus train in Lakeland, Florida, and the major highway/railroad crossing accident in Sycamore, South Carolina. He has seen, first hand, the tragedies left in the wake of accidents. Today represents his dedication to preventing other tragedies.

With this said, I would like to welcome you, challenge you to work hard and introduce you to Chairman Jim Hall.

A handwritten flourish consisting of a wavy line with a small loop in the center.

REMARKS BY
THE HONORABLE JIM HALL
CHAIRMAN, NATIONAL TRANSPORTATION SAFETY BOARD

November 1, 1995



Good morning. I would like to welcome everybody to this symposium, probably the first time so many leaders of government and the private sector have been gathered in one place to address one of the major hazards of transportation -- fatigue. With the help of the National Aeronautics and Space Administration (NASA), we have put together what we hope will be an educational and thought-provoking conference that will, in the end, save lives.

I want to make sure I acknowledge the tireless work of Julie Beal, the Safety Board's Director of Public Affairs, and her committee for planning, organizing and running this conference. And I want to thank Dr. Mark Rosekind of NASA for his invaluable contribution to the concept and organization of this event.

As you probably know, the National Transportation Safety Board is an independent federal agency with two major tasks: to determine the probable causes of major transportation accidents and to issue safety recommendations aimed at preventing such accidents. We fulfill this mandate in several ways: by investigating accidents, by conducting safety studies, and by convening symposiums like the one we're beginning today.

Although fatigue has assuredly been with us for a long time, it was not until the industrial age and the advent of complex machinery that fatigue became a major hazard to life and limb. With the increasing industrialization of society, people are exposed more and more to the dangers of fatigue. Today, we need only drive from our homes, live near railroad tracks, or board an airplane to face first-hand potential dangers from operator fatigue.

The Safety Board issued nearly 80 fatigue-related safety recommendations since 1972 to the modal administrations in the Department of Transportation, transportation operators, associations and unions. As a result of our experiences in investigating accidents in all modes of transportation over the years, we grew to appreciate the importance of human factors studies and established a human performance office in 1983.

In 1989, we issued three major safety recommendations to DOT, calling for a coordinated and aggressive federal program to address the fatigue problem in all sectors of the transportation industry. In the intervening six years, DOT launched initiatives to address these recommendations, and Secretary Peña will undoubtedly describe them to you in depth tomorrow.

The fact is, however, that while we all study the problem, accidents continue to happen. You will hear later this morning about some of the larger accidents the Safety Board investigated in recent years where fatigue was a cause or factor -- the EXXON VALDEZ; the Thompsonstown, Pennsylvania freight train collision; and the crash of a DC-8 at Guantanamo Naval Air Station are just three examples.

What is interesting about fatigue is that every one of us here knows exactly how it feels and what it does to us. We've all experienced the dramatic effects of extreme fatigue when we tried to drive an hour longer than we should, or we tried to stay up to watch a movie, or we tried to act interested listening to one of my speeches.

Oftentimes, though, the effects of fatigue are more subtle and, therefore, more insidious. In the past it was difficult to identify fatigue as a causal factor in an accident investigation. But we are getting better at it, and, more importantly, we're beginning to learn how to counteract it. If you don't already, you will have a good handle on this by the time you leave tomorrow afternoon.

The factors contributing to fatigue are becoming increasingly prominent. Our society now demands that goods be shipped anywhere in the country -- or even around the world -- overnight. Many factories have adopted just-in-time materials delivery.

Trucking deregulation might have been a boon to businesses and consumers by resulting in lower rates, but it didn't alleviate the problem of fatigue for truck drivers. On the contrary, it might have added to the pressures that lead to fatigue.

Commuter airline pilots often fly a dozen legs in one day, and after a shortened rest period, do it again the next day. The jet age made it possible for both passengers and crewmembers to experience jet lag, which can cause fatigue by rapid travel across time zones, that even rest cannot immediately alter.

As the demand for goods and the availability of transportation continues to grow, and the time we want to wait for such services continues to decrease, we see vehicles getting larger and larger:

- Jumbo jets now carry more than 500 passengers, and aircraft are on the drawing board that would carry more than 1,000.
- The average size of ships calling at U.S. ports grew five-fold in the last 50 years, with crew sizes cut in half. In many of the major ports, the normal clearance from the bottom of the harbor for these deep-draught ships is often as little as two feet.
- Where once we mostly saw 10-ton vegetable trucks on our highways, we now see double-bottomed and triple-trailer trucks on the interstates.
- More than 200 million hazardous materials shipments criss-cross the country every year by road and rail.

This conference will highlight for you the importance of fatigue countermeasures, and how they can be applied to prevent accidents in all modes of transportation. The American taxpayer invested millions of dollars in research into programs that examine fatigue. This forum presents an opportunity for us to learn spe-

cifically about the NASA countermeasures program, as well as sharing information on specific research projects currently underway.

In recent years, Congress has set up the National Commission on Sleep Disorder Research, and issued a report on the role biological rhythms play in fatigue. As I've already mentioned, DOT took initiatives on several fronts to study fatigue. Along with the trucking industry, DOT is conducting a truck driver fatigue study and an older driver study. We at the Safety Board early this year completed a major study on truck driver fatigue.

We applaud all that has been accomplished in the field of research from the government, academia and the private sector. But at some point we must decide that, while research should never end, the time for study must yield to a time for action. It is time to put what we have learned, and what has been provided to us by the taxpayer, into the hands of the transportation operators for the protection of the American people.

This conference is structured around another government funded study, the Fatigue Countermeasures Program developed by Dr. Mark Rosekind at NASA Ames Research Center. Although developed for aviation, it can be adapted for the other modes of transportation as well.

This kind of "cross pollination" between transportation modes is not unique. In fact, the Safety Board is always looking for innovative ways to address a transportation problem, even if it originates in a different mode.

Fifteen years ago, a concept called Cockpit Resource Management was developed for the aviation industry. Again originating from pio-

neering work at NASA Ames, this training method is now called Crew Resource Management. The Board recommended that the FAA and the airline industry adopt this training method that encourages teamwork, with the captain as the leader who relies on the other crewmembers for vital safety-of-flight tasks. The Safety Board recommended it for other modes, and it is gaining acceptance in the marine industry, which calls it Bridge Resource Management.

We believe that borrowing successes from one mode or one State for the betterment of another is nothing more than spreading the word on practical, cost-effective methods that work. We did just that more than 20 years ago when we saw how effective the few pipeline one-call systems were in preventing underground damage accidents. We asked all States to implement similar programs. Today, the entire country is served by these lifesaving programs.

To promote the use of these programs and others aimed at preventing these accidents, we convened a national excavation damage workshop last year.

Twenty years ago we learned of the "Operation Lifesaver" rail/highway grade crossing program that was in use in six or seven States. We asked all States to initiate these programs and urged that a national coordinating effort be launched. Today, 49 States have Operation Lifesaver programs and the number of deaths at crossings have been reduced by half.

Another major success story we can point to deals with how the States are combatting the drinking-and-driving problem. Based on what we found to work in a few States -- raising the drinking age and instituting administrative li-

cense revocation, for example -- we asked all States to follow suit. As a result of our efforts and those of many others, including grass roots organizations, drunk driving fatalities dropped 35 percent in the last 12 years. The age-21 laws alone saved almost 15,000 lives.

And that, after all, is why we're here -- to save lives. It is a fact that more than 43,000 Americans lost their lives in transportation accidents last year. That should provide us with all the motivation we need.

Tomorrow, after hearing from Secretary Peña, you'll be breaking into working groups in which you and your fellow professionals will determine how to adapt the NASA Ames Fatigue Countermeasures Program to your mode's specific needs.

The fruits of this conference won't be known for years. The trucking industry, for example could very well develop useful fatigue countermeasures for its longhaul drivers. But it is estimated by industry that trucks account for just four percent of highway fatigue-related crashes. If these numbers are true, imagine the impact of these countermeasures when they eventually spread to the general automobile-driving population, the source of the other 96 percent of fatigue-related highway crashes.

I believe this conference will prove to be a pebble thrown into a pond. The ripple effect will be felt for many years to come as all of you begin to apply what you've learned here to the betterment of your company or industry. I'm proud that NASA and the National Transportation Safety Board were able to put this conference together, but its success depends on you.

With all this said, it is time to move on with the program. We will begin today with a presentation by Jim Danaher. Jim is currently the Chief of the Operations Division in our Office of Aviation Safety, and he has been with the Board virtually since its inception as an independent agency. More importantly, Jim was one of the founding fathers of the human performance division at the Board and has seen first-hand the evolution of our ability to document fatigue as a significant safety factor in transportation.

Jim will be describing the history of the Safety Board's investigations into fatigue-related accidents. Thank you for coming, and now let's get to work.



REMARKS BY

THE HONORABLE FEDERICO PEÑA

SECRETARY, DEPARTMENT OF TRANSPORTATION

November 2, 1995



I want to say a special welcome to the representatives from Europe, the Mideast, and Asia who are here. I don't know if you're over your jet lag yet. But on Sunday, I leave for a 17-day, eight country trip to Asia, and I'm about to have first-hand experience with transportation fatigue!

I'll be on a trade mission to promote American products and services and open aviation markets. Since President Clinton took office, the private sector has created 7.5 million jobs - 2 million of which are export-related. We have signed 80 trade agreements.

As trade expands, 10 years from now you'll see truck traffic up 20 percent and rail traffic up a comparable number. Now, we have one-and-a-half million people flying every day in the United States, and within 10 years, it will be two-and-a-half million, every day boarding planes.

As Transportation Secretary, I want travellers to have a pleasurable experience. I want our companies to be globally competitive, and that means delivering people and products on time and efficiently. But most of all, I want safe roads, and safe skies, and safe waterways for the American public.

Sometimes, we get wrapped up in people taking different positions. Perhaps the unions wanting a day's pay for a day's work ... perhaps the transportation companies wanting more flexibility and speed ... and the traveling public demanding people flying planes or driving buses who are not tired and not falling asleep at the wheel.

Sometimes there's a disconnect between what everybody wants. But my bottom line is: the American people must trust us to make sure all transportation sectors are operating safely. Period.

When I became Transportation Secretary, I set as one of my highest priorities improving safety because 43,000 Americans are killed every year in transportation accidents.

I'm finding, as every other Transportation Secretary found, safety improvements don't come cheaply or easily. We have to work hard for every life we save, and as we see traffic increase, we'll have to work even harder.

I'm constantly conferring with leaders in the airline, railroad, truck, and bus industries to see how we can work together for the sake of the public and their employers.

Today, for this conference, I'm responding to NTSB Chairman Hall's challenge by releasing the Department of Transportation's: Fatigue Program Overview. It summarizes the research and technology development, public education, outreach, and operational strategies being used by my Department.

I commend the group of senior managers, who are coordinating our research. They meet regularly with the NTSB to keep the Board apprised of our efforts to respond to their fatigue-related recommendations.

The Department also will be assuming responsibility for the Fatigue Resource Directory, assembled for this symposium. We envision that you can access it on the Internet.

In the breakout sessions, you'll be discussing the overview in depth, but let me make five observations:

First, I'm convinced that changing human behavior has to be the next frontier to improving safety. Human factors cause a third of all railroad accidents and are the number one cause in aviation accidents. Operator error is probably the most important single factor in truck and bus accidents.

Second, if it's human behavior we must change, then we need to educate, and not just regulate. I know so much of our time is spent developing rules for dealing with fatigue. But there are several realities after you make the rules, such as how do you mandate rest? How do you monitor rest periods?

You can tell a person: "this is the time for you to sleep," but it doesn't do us any good unless he sleeps. It's really a matter of personal responsibility.

It's like having a seat belt in a car. The law says buckle up, but three out of 10 people still don't take the personal responsibility of buckling. And if we hadn't spent hundreds of millions of dollars educating the public far fewer would be buckling.

When it comes to fatigue, every person at every level of an organization -- each driver, each operator, each dispatcher, each manager must personally be responsible.

Third, it's important to understand fatigue is not just a matter of rest. Lots of factors cause fatigue, such as pressures from the job, and the operating environment, and whether it's dark or light. We need to look into those factors further.

Fourth, the traveling public has just as much right to expect transportation operators to be unimpaired by fatigue as they have the right to expect operators to be unimpaired by alcohol or drugs.

We now have the capability to test for alcohol or drugs. We don't have all the fatigue testing capability we would like -- yet.

But we've been obtaining encouraging results with both fitness-for-duty testing devices and with unobtrusive, noninvasive techniques to detect the onset of performance deterioration in operators. I hope these countermeasures are used in the near future.

A few months ago, I was in Portland with the President at a regional economic conference. And the president of Freightliner told us about work they were doing on ventilation systems in cabs to alleviate fatigue.

Fifth, we should be focused on how tired workers perform, rather than how tired a worker feels at the end of the day.

The danger from fatigue is not just that someone will nod off to sleep at the controls of a plane, ship, train or motor vehicle, although I'm sure all of those have happened.

The insidious danger is that the operator may become dulled enough to miss -- or misinterpret -- a critical danger signal, or be slow in responding to it.

In transportation safety where the commercial operator may be responsible for the lives of hundreds, we must guard against the one-in-a-million risk because that is what the public demands.

Now, let me address a few issues now before Congress. If ever there was an issue the federal government took the lead on, and did it well, it's highway safety. That is about to come unraveled.

Congress is about to eliminate the 55 miles-per-hour national speed limit, which we credit for saving more than 2,000 lives a year.

And ... Congress is about to eliminate motorcycle helmet laws. The last time they did that, in the 1970s, and had the states decide, 27 states decided there's no reason to have a helmet law. So, what happened? Motorcycle deaths increased 61 percent.

And ... Congress is about to exempt a large part of the commercial truck fleet from our truck safety regulations.

It is distressing. Here, we hold conferences like this. We do all of this research on fatigue

because we value life and the health of the nation and we know we can save one, two, or three lives at a time. But with one stroke, Congress is about to put at risk thousands of lives.

States would set their own speed limits. I met with state transportation secretaries from all 50 states on Monday. Many of them disagreed with me on who should be responsible for setting limits, but I told them we need to agree that safety must come first. We can't retreat on safety, because we have made too much progress.

We're making progress in every transportation sector.

In motor vehicles, the percent of all accidents caused by drunk drivers is down. Seat belt usage is up.

We have the world's safest air system, and are pursuing a goal of zero accidents.

In rails, 1994 was the safest year in history. Unfortunately, last week, there was a tragic school bus accident at a grade crossing in Illinois. I've formed a task force to review the design and construction approval process of highway and rail crossings, so that if there are holes, we'll find them.

Let me end on this. It's up to us ... each of us in this room ... to figure out how with all of that increased traffic we will see in the future, we can keep improving the safety record.

To ask what can we do to delay loss of alertness. To detect it if it occurs. And to prevent fatigue-based accidents.

So, I thank you for all your good efforts. As the President says: the best is yet to come, and it is.

Thank you very much.



REMARKS BY

JIM DANAHER

**CHIEF, OPERATION FACTORS DIVISION
NATIONAL TRANSPORTATION SAFETY BOARD**

November 1, 1995



Good morning ladies and gentlemen! I'd like to add my welcome to each of you to this symposium on fatigue countermeasures and commend you for your efforts to be here. The NTSB and NASA staffs have worked long and hard to organize this meeting and to make it as useful as possible. I sincerely believe that when you leave tomorrow, you will feel that your time and effort were well spent.

I'd like to provide a brief overview of the Safety Board's accident investigation experience that illustrates the nature and pervasiveness of human fatigue in transportation accidents. In its investigation of numerous accidents in all transportation modes, the Safety Board has identified serious and continuing problems concerning the far-reaching effects of fatigue, sleepiness, sleep disorders, and circadian factors in transportation system safety. We have seen repeated instances of poor scheduling of work and rest periods in all transportation modes that have or might have affected adversely the performance of operating personnel.

The investigations also indicate that many transportation industry employees and supervisors fail to receive training on the problems associated with work and rest schedules. And with a few exceptions, management and labor

segments also fail to properly consider the harmful consequences that irregular and unpredictable work and rest cycles can have on people who operate vehicle.

Some of the clearest examples of the effects of operator fatigue problems are seen in major highway accidents. A Safety Board study of 182 fatal heavy truck accidents found that driver impairment due to fatigue was the most frequently cited single cause or factor (31 percent) in the accidents investigated. Additionally, one third of the drivers who were identified as being fatigued were also impaired by alcohol and/or drugs. The Board stated, "Some truck drivers apparently do not realize that fatigue is aggravated after the initial effects of stimulants. Sleep deprivation becomes a deficit that drugs cannot overcome. Further, depressants, such as alcohol, aggravate fatigue and reduce the initial effect of stimulants.... The only way to repay the 'deficit' is to sleep."

The Board recommended that major trucking and shipping associations encourage their members to participate in education programs on the effects that long working hours and irregular schedules have on driver fatigue. The establishment of education programs covering the interaction of alcohol/drugs and fatigue were urged as well.

The Safety Board has also found that fatigue is a factor in railroad accidents. The January 1988 collision of two Conrail trains near Thompsontown, Pennsylvania, is a good example of the way fatigue and irregular work schedules play a causal role in accidents. At 7:54 a.m., a westbound Conrail freight train collided with an eastbound Conrail train, fatally injuring the engineers and brakemen on both trains, and resulting in more than \$6 million in damage.

The Safety Board determined that the probable cause was the sleep-deprived condition of the engineer and other crewmembers of the eastbound train, which resulted in their inability to stay awake and alert, and their failure to comply with restrictive signals. Factors involved in the crewmembers' sleep condition were their unpredictable work and rest cycles, and their voluntary lack of proper rest before going on duty. The inadequacy of the locomotive safety backup alertness systems also contributed to the accident.

This accident illustrates several aspects of existing railroad operations that can adversely affect train crews' performance of their duties, and, ultimately, the safety of rail transportation. Specifically, the Safety Board found that the engineer and brakeman of the eastbound train probably were suffering chronic sleep deprivation because their work shifts and off-duty periods at home were unpredictable and irregular. Nevertheless, the crewmembers customarily participated in the normal work and living routines of their families, sleeping during conventional night hours. They did not attempt to get meaningful daytime sleep, even though they anticipated calls to work late in the day or at night. Instead, they would try to get by without adequate sleep until their next off-duty period. None of the crewmembers of

the train that failed to comply with the signals had more than two hours of restful sleep during the 24 hours preceding the accident. The Safety Board concluded that the crewmembers' sleep-deprived condition was compounded by the monotonous environment of the locomotive cab, and possibly by their failure to eat a meal for at least 13 hours before the accident. Finally, we found that the engineer of the errant train was able to defeat the safety redundancy intended by the automatic train stop (ATS) device. Apparently, the act of acknowledging the signal became so routine that the engineer was able to accomplish it without being alert.

Nearly two years later, a remarkably similar train collision occurred in California that also was attributed to operator fatigue.

On November 7, 1990, at about 4:11 a.m., two Santa Fe Railway Company freight trains collided head on in Corona, California. The westbound train, which was traveling from Barstow, to Commerce, California, was directed onto the Corona siding. But it passed the stop signal, and the lead locomotive reentered the main track area, blocking all movement on the main track. The eastbound train, was on the main track and collided with the westbound train. Each train had three-person crews.

As a result of the collision, the entire crew of the westbound train was killed, and four locomotives and three rail cars were derailed. The engineer and conductor of the westbound train sustained serious injuries and the brakeman was killed; all three locomotives and five rail cars were derailed. Total damage was over \$4 million.

The Safety Board determined that the probable cause was the failure of the westbound train engineer to stop his train at the stop signal because he was asleep. Contributing to the accident was the failure of the conductor and the brakeman to take action to stop the train, probably because they too were asleep. Also contributing to the accident was the irregular unpredictable work schedule of the westbound train engineer; the railroad's lack of a policy or procedure for removing crewmembers from service when they are not fit for duty because of lack of sleep; and the inadequacy of the Federal rules and regulations that govern hours-of-service.

The March 1989 grounding of the EXXON VALDEZ in Alaska demonstrated the role fatigue plays in marine accidents. Although the Safety Board's report on that accident cited the master of the tanker in its probable cause statement for failing to provide "a proper navigation watch" around an ice flow, it also determined that the third mate, who had assumed the watch, was fatigued at the time of the grounding and overburdened by an excessive workload.

In safety recommendations to the Coast Guard, the Exxon Shipping Company, and other shipping companies, the Safety Board pushed for improvements in regulations, policies, and procedures concerning vessel manning levels, work hours, and off-duty time for rest.

Costs to individual companies of these accidents is staggering. As I am sure you are aware, the grounding of the EXXON VALDEZ resulted in lost cargo worth \$3.4 million and in damage to the vessel of \$25 million. To clean up the spill and settle associated law suits has cost \$3 billion to date. In addition, Exxon was ordered to pay punitive damages of \$5 billion.

Approximately three months after the EXXON VALDEZ, disaster another marine accident occurred that was attributed, in large part, to the adverse effects of fatigue.

At 4:39 p.m. on June 23, 1989, the Greek tankship WORLD PRODIGY, en route from Bulgaria to Providence, Rhode Island, carrying more than 195,000 barrels of diesel fuel grounded on Brenton Reef in Rhode Island Sound. At the time of the grounding, the vessel was under the navigational control of the master. As a result of the grounding, the hull of the WORLD PRODIGY sustained extensive damage, and spilled 7,000 barrels of diesel oil into Rhode Island Sound and Narragansett Bay. Because of the nature of the oil and of the warm temperatures during the days immediately following the accident, much of the spilled oil quickly evaporated, minimizing the damage done to the nearby coastline. There were no deaths or injuries. Damage to the vessel was estimated at more than \$1 million.

The Safety Board determined that the probable cause was the master's impaired judgment from acute fatigue, which led to his decisions to decrease the bridge watch and attend to nonessential tasks during a crucial period in the ship's navigation.

Let's now turn to aviation. On August 18, 1993, at about 5:00 p.m., a DC-8 freighter, registered to American International Airways, crashed about 1/4 mile from the approach end of the runway, after the captain lost control of the airplane while approaching the Leeward Point Airfield at the U.S. Naval Air Station, Guantanamo Bay, Cuba. The airplane was destroyed and the three flight crewmembers sustained serious injuries. Visual meteorological conditions prevailed. The flight was conducted under the regulations governing Supple-

mental Air Carriers, as an international, non-scheduled, military contract flight.

The flightcrew had been on duty about 18 hours and had flown approximately nine hours at the time of the accident. The company had intended for the crew to ferry the airplane back to Atlanta after the airplane was offloaded in Guantanamo Bay. This would have resulted in a total duty time of about 24 hours and 12 hours of flight time, the maximum permitted under the rules for supplemental air carriers on overseas and international flights.

The NTSB determined that the probable causes were the impaired judgment, decision-making, and flying abilities of the captain and flightcrew due to the effects of fatigue; the captain's failure to properly assess the conditions for landing and maintaining vigilant situational awareness of the airplane while maneuvering onto final approach; his failure to prevent the loss of airspeed and avoid a stall while in the steep bank turn; and his failure to execute immediate action to recover from a stall.

Contributing factors were the inadequacy of the flight and duty time regulations applied to Supplemental Air Carrier, international operations, and the circumstances that resulted in the extended flight/duty hours and fatigue of the flightcrew member.

This was the first time the Board cited fatigue as a causal factor in an air carrier accident.

The Board also identified fatigue as a concern in its commuter airline safety study. Human fatigue was further addressed by the Board in the investigation of a non-fatal-in-flight loss of control and forced landing at Pine Bluff, Arkansas, of a Continental Express flight on April 29, 1993. The Board cited fatigue in-

duced by the flightcrew's failure to properly manage provided rest periods as a contributing factor, and recommended that commuter air carriers provide aircrews information on fatigue countermeasures.

This accident brought to the attention of the aviation community the need for flightcrews to be adequately rested before a flight. The FAA has begun reviewing its rest and duty time rules and regulations pertaining to flightcrews, and intends to issue a notice of proposed rulemaking regarding flight and rest requirements for both the major and the commuter carriers. The Safety Board has accepted FAA's action plan.

Nearly six years ago, following a series of major fatigue related transportation accidents, the Safety Board recognized the need for more concerted action on fatigue problems in transportation. While there had been some private research conducted on this issue, in 1989 the Safety Board was unaware of any systematic activity by the Department of Transportation to address these safety concerns. Then the Board issued safety recommendations to the DOT urging that coordinated research programs be expedited, that educational material be developed and disseminated to transportation industry management and other personnel regarding this issue, and that all DOT regulations related to work scheduling and hours-of-service be reviewed and upgraded to incorporate the results of the latest research.

The Secretary of Transportation responded to these recommendations later that year, citing a number of initiatives. We will receive a further update on the status of these DOT initiatives from Secretary Pena tomorrow.

The problems of human fatigue in transportation system safety have been included as a part of the Safety Board's "Most Wanted" Transportation Safety Improvement Program since 1990. Since that time, considerable progress has been made by government, industry, and academia in addressing the problem. But much remains to be done. The idea for this symposium originated with our Chairman, and we on the Safety Board staff are firmly committed to make it one more step in our common efforts to improve the safety of America's traveling public. We earnestly seek your support in this very worthwhile goal -- not only in the next two days, but thereafter as well.

Thank you!



Physiological Considerations of Fatigue

Dr. Mark R. Rosekind

Fatigue Countermeasures Program NASA Ames Research Center

November 1, 1995 - Morning Session



Thank you Chairman Hall. On behalf of NASA, the Ames Research Center and the Fatigue Countermeasures Program I welcome all of you. We are all extremely pleased to see both the size of the crowd, which indicates the interest in this topic, as well as the diversity of the individuals that are here. And while we may be up here today, your work certainly will begin tomorrow.

The first item is to review today's program. During planning, we were pleased to have an entire day to talk about some of the scientific information that is available about fatigue. Even with an entire day available, we ran out of time when you see how much we are going to try and cover. Essentially, we have presentations in groups of three.

The first presentation today will describe the physiological considerations that underlie fatigue, and then we will talk about sleep disorders in a presentation by Dr. Allan Pack. Then, in what I think is an important bottom line, how fatigue affects human performance, presented by Dr. David Dinges.

Immediately after these three presentations, we begin addressing what strategies are available to manage fatigue in transportation. Therefore,

the next six presentations will deal with specific strategies. After some introductory remarks, I will describe some basic sleep habits we believe everybody should know about, then napping strategies will be discussed by Dr. Dinges, alcohol, sleep medications and caffeine will be discussed by Dr. Tom Roth. After that, we will hear about melatonin and bright light, different strategies to try to adjust the circadian clock, presented by Dr. Charles Czeisler. This is a hot topic, yesterday's Newsweek has melatonin as a cover story, and we can not have a symposium like this and not at least address melatonin and other circadian shifting strategies.

Then Dr. Dinges will talk about technology and scheduling approaches. And we will end the day discussing educational approaches, which is what really initiated this symposium. We feel that education is really the foundation for any other activities to manage fatigue in transportation.

The very final presentation of the day will deal with a resource directory. We thought it was important that besides providing scientific information, we should provide resources for people to use after the symposium. When you go home as individuals or to your organiza-

tions, you will be able to access resources that would help you implement the information obtained over these two days.

The speakers who are here today are internationally acknowledged as experts in the field. When they come up I am going to actually be very brief in introducing them because I want them to be able to get to their content. There is more detailed information about them in the symposium binder that you have received, including how to contact them for other resources. We are very fortunate to have such a distinguished group of experts here today. I do want to acknowledge there are many other people here in the audience who are active in this area. And we are looking forward to your expertise, participation and contributions to tomorrow's working groups.

One of the things we have during the day are two 30 minute question and answer periods. In your binders you have blue index cards. If you have questions throughout the day, please write them down on the cards, pass them to the outer aisles, and individuals will pick them up and bring them to the podium so we can handle the questions off the index cards by our expert panels.

When I was thinking about the "NASA" approach to managing fatigue in transportation, I realized there were two components. The first was that our approach acknowledges that transportation is a 24 hour, global activity. It is varied, complex, and requires flexibility. And even if we did not have this symposium, transportation operations are going on now and they will go on tomorrow. The objective then, is how do we incorporate what is currently known about human fatigue and strategies to manage it, into current operations. The second component is that as you learn about how all these

approaches are complex and varied, it should be clear that there is no one approach or strategy that will cure all of fatigue in transportation. Part of our agenda today is to help unravel some of the complexity and describe some of the strategies that are available to manage fatigue in transportation operations.

Charles Lindbergh wrote this about his historic first transoceanic flight crossing the Atlantic in 1927. "My mind clicks on and off. I try letting one eyelid close at a time while I prop the other open with my will. But the effort's too much, sleep is winning, my whole body argues dully that nothing, nothing life can attain is quite so desirable as sleep. My mind is losing resolution and control." He wrote this about his experience during his historic 1927 flight, and I am going to use aviation as an example, as it is one of the most "modern" forms of transportation.

In the almost 70 years since Lindbergh's historic transoceanic crossing, technology, automation, and operational demands in all modes of transportation, have evolved significantly. For example, from the five people required to fly a Pan Am clipper ship to the three required to fly a 727, and from three down to two flight crew in today's glass cockpits that are available in the 747-400 and the new 777. In the almost 70 years since Lindbergh's flight, the technology, the automation, and the operational requirements have evolved tremendously. The human operator who is in the middle of all of that has not evolved at all. What we are going to talk about first this morning is what some of the physiological considerations are that underlie fatigue.

What I want to do is start with a model that we have created to understand fatigue in operational settings. There are two major physiologi-

cal factors that I am going to talk about. One is sleep and sleep loss. The other physiological factor is circadian rhythms and their disruption. These are the two main physiological factors that underlie fatigue. When people see this model, they often ask "Well, what about diet, what about stress, what about workload?" Yes, all of those factors could affect fatigue. However, if you look at the scientific literature on what is available to understand how we could quantify those factors and fit them into this model, it is currently very small at this point. When more scientific information becomes available about how stress, diet, workload, etc., fit this model of fatigue, then it will be incorporated.

However, the two physiological factors that we have a tremendous amount of information about are the sleep and the circadian processes. We must also acknowledge that operations affect these physiological factors as well.

What is important is that all of these factors come together in the human operator, in the middle of the operation. We use the word fatigue like the word stress. Everybody can relate to it, everybody understands it. But people use a wide range of descriptors to explain fatigue --sleepiness, tired, I'm out of it, I'm gone, etc. Today we will be focusing on the word fatigue as the summation of all the possible variety of descriptors. And I will be primarily addressing these two physiological processes -- sleep and circadian rhythms.

While the focus of this material today is on its application to transportation operations, as human beings, all of us will find this information relevant as it affects us every single night when we go to bed.

A lot of people think that sleep is like taking your car, putting it in the garage at night and shutting it off. When your head hits the pillow, everything shuts off. If you are lucky, in the morning, you kick start and everything begins again. Sleep is actually a very dynamic and complex physiological state, and it actually has two specific components.

The sleep state most familiar to people is called REM sleep or rapid-eye-movement sleep, when you dream. The other sleep state is non-REM sleep, non rapid-eye-movement sleep. Non-REM sleep is like taking that car into the garage and putting it in neutral for the night. When you go into non-REM sleep everything in your body and your brain slows down; physiologically, mentally, everything slows down for the night. Non-REM is divided into four stages -- one, two three, four.

The deepest stages of sleep, at least in terms of waking someone, are non-REM three and four. This is important because if you are in a laboratory, asleep, all wired up, and I come in to wake you up in non-REM stage three or four, it is a time when your brain and your body are in their deepest sleep. If I come in to wake you up, first of all it could take one, two or three minutes to wake you up. And when you did wake up, I would say, tell me what was going on in your mind? You would probably say very little and not make much sense, this is the deepest sleep. So, if you wake somebody up in deep sleep, the individual can be disoriented, groggy, sleepy, for 10 or 15 minutes after that. This is called sleep inertia. Later when we talk about napping strategies in an operational setting, you would not want somebody waking up and being sleepy, disoriented, groggy. So understanding the basic physiology is very important.

REM sleep is like taking that car into the garage and throwing your foot on the accelerator and the brake at the same time. REM sleep is a time when your brain is extremely active, that is like having your foot on the accelerator. What is it active doing -- it is dreaming. In REM sleep, when your brain is dreaming, it is actually sending signals to your body to do whatever it is that you are dreaming about. But what's that foot doing on the brake? That foot on the brake essentially prevents those signals from getting to your body, so that you do not enact what you are actually dreaming about.

The dreaming brain is sending signals to your body to do whatever is going on in your dream. It is a very dynamic, complex state with a lot of activity going on physiologically. So while non-REM is slow, REM is a time of incredible activity. Every night when you go to sleep you go through what is roughly a 90 minute non-REM/REM cycle. You spend about 60 minutes in non-REM and about 30 minutes in REM sleep. That's a statistical average because no human being actually sleeps on a cycle that exact.

Most of the deep sleep that you get occurs in the first third of the night. So, if you are going to take a nap or a short sleep period and you want to avoid sleep inertia (that is, waking up sleepy, groggy, etc.) then the length of the nap or the sleep period is going to be critical. Again, most of that deep sleep will occur in the first third of the night. Also, REM periods occur on a more regular basis and are longer later in the night. They are also more intense physiologically later in the night.

The most dramatic changes that occur in sleep occur as a normal function of aging. As you get older, your sleep becomes less deep, more fragmented and you do not get the same total

number of hours at night. Even the noise level of a 747 at 500 feet over a child's head; the child's brain does not acknowledge that the noise exists. The child would not go from deep sleep to a lighter sleep or wake up. It is as if the noise does not exist. And that blissful childhood sleep goes away with age.

As you get older your sleep gets less deep. There are some people who feel that you actually lose all of your non-REM stage three and four sleep. Sleep becomes more fragmented, and your brain's ability to give you eight consolidated hours a night goes down with age. Does that mean you need less sleep as you get older? No. And how do we know that? Because even though you sleep less at night, people start getting sleepy or napping more during the day. If you did not need the sleep, there would not be the subsequent increase in daytime sleepiness.

Also, the quality of sleep obtained can be as critical as the quantity. You can get eight hours of sleep, but if it is disrupted you can still wake up feeling fatigued and non-restored. For example, there is a sleep disorder where the leg muscles twitch. Your right leg, your left leg, or both legs twitch. Why is that a problem? Because every time they twitch, they wake you up, possibly three to 400 times a night. This sleep disorder is called periodic limb movements. It is literally like somebody coming in to your room and saying "wake up," leaving the room for 30 seconds, comes back, says "wake up" again, and continues that 300 times through the night. So you can sleep for eight hours, but in the morning, you have literally had 300 awakenings during the night. The operational equivalent is trying to sleep during the day in a hotel, or a strange facility, when people are vacuuming or other things are going on that can disrupt sleep quality. So the

quality of the sleep you get can be as critical as the quantity.

Sleep loss is a common experience in many types of operations. How do you recover? When you are recovering from sleep loss, you recover by sleeping deeper, not necessarily a lot longer. For example, there was a high school student in San Diego, named Randy Gardner. In the early 70s, he wanted to break the world's record for staying awake. At that time, the record for continuous wakefulness was 260 hours. Randy stayed awake for 11 days straight, 264 hours of wakefulness. Some people might say that since we are usually awake for 16 hours and sleep for eight hours, that represents a two to one ratio. So, to make up sleep in that ratio, after being awake for 264 hours, Randy should probably sleep 132 hours. After being awake for 11 days, Randy went to sleep and slept for about 14 hours, woke up in the middle of the night, stayed awake for 24 hours, and then slept for about 9. He did sleep slightly longer but did not make up the sleep hour for hour. He made it up by sleeping deeper, not significantly longer.

Studies in the scientific literature suggest that you need about two nights of your normal amount of sleep, at your usual sleep time to recover from sleep loss. Two nights help to restore both the night time sleep architecture and help to return your waking level of performance and alertness to roughly baseline levels.

Today, scientific research has clearly demonstrated that sleep is a vital physical need. It is as critical to human survival as food, water or air. If a human does not eat or drink or have oxygen--the individual would die. Just like these other vital physical needs, you need sleep for human survival.

Another important concept is that as you lose sleep, it builds up into a sleep debt. Currently, estimates suggest that in the United States most people get anywhere from one to one and a half hours less sleep than they actually need. What that means is that during a regular work week you accumulate a sleep debt so you are going into a weekend seven and one half hours in the red. Think about it like a bank account. When you lose sleep it builds up into a sleep debt. This is important because as you lose sleep, you get sleepy. If you do not eat you get hungry. If you do not drink something you get thirsty. Hunger and thirst are powerful and important signals from your brain that indicate your need for food or water. Sleepiness is your brain sending you a very powerful signal saying that you need sleep.

Sleepiness is such a powerful biological signal, that in an uncontrolled, spontaneous way, no matter how motivated, well trained, or professional, your brain can shut you down regardless of your situation. Even in a potentially lethal situation, your brain can shut you down to get the sleep that it needs. However, you do not have to fall asleep to have that sleepiness affect your performance. Every aspect of being a human being, every aspect of performance and capability, can be degraded with sleep loss and sleepiness. The ultimate is nodding off.

Does that mean that in every situation that involves sleep loss and sleepiness there will be an incident or an accident?" No. However, it does mean that with sleep loss and sleepiness a situation exists in which you are vulnerable to a performance problem that could end up in an incident or accident. Dr. John Lauber, a former member of the National Transportation Safety Board, has said that, "Not having an accident does not mean you have a safe operation."

There are two components of sleepiness to describe. One is physiological, reflecting an underlying biological process. You lose sleep you get sleepy. The only way to reverse that physiological need for sleep is to sleep. If you are physiologically sleepy because you have lost sleep, to reverse it, you must sleep. You can not meet this physical need by just “resting” your eyes, or rolling the window down, or cranking the radio up, the only way to reverse that physiological need for sleep is to get sleep.

But let us distinguish physiologically what you need from how you feel. Right now you could rate how sleepy you feel. For example, on a scale from one, wide awake and alert, four you are moderately sleepy, seven, you are becoming foggy and you know sleep is coming soon. However, rating is affected by the environment you are in. If you are in an interesting, exciting environment, as time goes by you may not feel tired or readily experience fatigue. Put yourself in an environment where external stimulation is stripped away and you could fall asleep. So when someone says that a boring lecture “put them to sleep,” it may not be the lecture. For example, if you need eight hours of sleep and get eight hours, before going to a boring lecture, you come to the lecture and what do you do? When it gets boring, you read, you write a letter, you do something else, you are bored. But you do not fall asleep. If you only got six hours of sleep, there will be a pressure for you to fall asleep, especially in the right circumstances. So, you go into a room for the lecture, all the lights are shut off for slides that are hard to read, maybe uninteresting, and a speaker drones on. Everything in the environment that might help you to fight the sleepiness has been stripped away. The underlying tendency to fall asleep, the pressure for sleep will emerge and you could spontaneously, in an uncontrolled way, fall asleep.

There can be a discrepancy between self-report ratings of sleepiness and physiological sleepiness. We commonly think “I know how tired I am, I’ve done this before, I’m motivated, well trained, I know how sleepy I am.” However, human beings can be highly inaccurate, especially if already sleepy, in knowing how alert they are and how their performance is being affected.

This discrepancy can be important operationally. If you have been on a difficult schedule involving sleep loss or circadian disruption, you may believe fatigue is a factor. You look at someone next to you who has been on the same difficult schedule, and you ask them how they are feeling. When the individual says they are doing great, you may not want to fully believe their assessment. You can feel “fine and not tired” and be falling asleep within minutes. There can be a discrepancy between how people think they are doing and how sleepy they are physiologically.

There are many diverse factors that can affect sleepiness at any given moment. The human brain is programmed to make you maximally sleepy two times during the day. One window is from about three to five a.m., when most people are sleep, and the other window, is from about three to five p.m. That afternoon dip, when you start getting sleepy, is not because you just had a big lunch, or because that afternoon business meeting is boring. Your brain is programmed to make you sleepy during those times. Studies have demonstrated that whether you eat or not, you will get sleepy during that afternoon window of sleepiness. If you are at work during those times, it means that you are awake and working at times when your brain is programmed to have you asleep. If you are looking for a time to put a nap, these windows are good places to start, because they

are essentially times when your brain is programmed to have you asleep.

Next we will discuss circadian rhythms, the physiological rhythms that fluctuate on a 24-hour basis. There are many examples -- everything from the physiological to the behavioral (for example, performance) -- that fluctuate on a 24-hour basis.

There is a clock located in the suprachiasmatic nucleus, or SCN, of the hypothalamus that provides the control for these 24-hour physiological rhythms. The SCN operates somewhat like a timer that controls your lights at home or your sprinklers. If you were in a cave and could live on any schedule you want, it ends up that your internal body clock actually runs longer than 24 hours. It runs on about a 25-hour day. There is some new literature that suggests it may be closer to 24 hours.

The important point is that the natural tendency of your internal circadian clock is to run longer than 24 hours. So if you let the clock run on it's own, it actually likes to run a little bit longer.

How does the clock know what time it is? It appears that some of the most powerful cues for the clock come from the environment. One important external cue is sunlight, or bright light. There is a path way from the retina in your eye to the SCN in your brain, so that light can tell the clock the time. There are a variety of other cues from our environment that also help the clock know what time it is. What can create physiological problems is when you take the clock and put it on a new shift schedule, or put in a new time zone, it does not adjust immediately. It can take from a few days to weeks for the internal clock to adjust to a new schedule or new environmental time zone.

Shift work can involve any schedule when you are awake, active, working, at a time when your brain says you should be asleep. That situation requires that you override the biological process which has you programmed to be awake during the day and sleeping at night. One obvious conflict is trying to work during the night when you are biologically programmed to be asleep. Conversely, there is difficulty of trying to sleep during the day when you are biologically programmed to be awake. This creates a conflict between the environmental cues and internal circadian rhythms. One difficulty is that many situations involve continually shifting the clock around. For example, shift workers that go back and forth between schedules, or revert to day time schedules on their days off. Another example is crossing multiple time zones, returning home, readjusting to a home schedule, and then another series of multiple time zone crossings. Some believe that the longer one stays on a night shift that eventually the body will "adapt." The available scientific data indicates that being on an altered shift schedule, like nights, for a prolonged period of time does not lead to an adjusted internal circadian pattern. And why not? When a night shift worker leaves the job, the individual might get in the car to go home and drive in the sunlight. The sunlight tells the internal circadian clock that it is morning time and works to reset it on a day-light schedule. This provides mixed cues to the internal circadian clock and prevents physiological adjustment to the night shift.

Jet lag, of course, is a modern physiological challenge. It involves an abrupt change, taking the clock, putting it in an environment out of step with what is occurring internally. Again, it creates the situation where the environmental cues are out of synch with the internal circadian rhythms. When the internal clock

is shifted to a different schedule or a different time zone, all of the internal physiological patterns do not resynchronize all at once. Different internal circadian rhythms resynchronize at different rates. So it might be a few days for one physiological pattern to get back into synch, while others might take a week.

The different symptoms of shift work and jet lag are similar to those experienced with sleep loss. However, one that is a little different is the occurrence of stomach problems. Why would shift workers have more complaints about things like upset stomach, ulcers, etc.? This would occur when people are eating at times when their stomachs are not ready to digest.

Now, there are some factors we know of that can affect adaptation of the internal circadian clock. While some of these involve aviation examples, the factors affect shift changes, (like crossing hours), whether they be time zones or just going from day to night shift. The more time zones you cross the more difficult it is for the internal clock to adapt. Again, this is the same consideration as going from day to swing to night shift. The more hours you have to cross the harder it is for the body to adjust. There is some flexibility in the circadian clock, that allows about one to three hours of adjustment.

But there is a lot of individual difference in these factors. Such that, for some individuals the one hour time change associated with daylight savings time is sufficient to wreak havoc on their internal circadian clock.

Many people have heard about evening types and morning types, owls and larks. Owls are individuals who go to bed late, like to get up late in the morning. And the morning types,

or the larks, are the ones that actually go to bed very early, like at 9:00 p.m. They are awake at 5:00 a.m., ready to face the day.

There is a very small scientific literature that suggests evening types may adapt a little bit faster than morning types to altered schedules. However, most people do not fit into these extreme categories and the distinction has not been demonstrated to be useful for any type of selection.

As a normal part of the aging process, not only does your sleep change, but your internal circadian clock's ability to adjust to schedule and time zone changes also slows down with age.

Many people have had the experience flying that suggests it is easier physiologically to adapt when you are going in a westward direction than when going easterly. Also, in shift work, it seems easier to adapt when going to a day, swing, night shift schedule than when going backwards. Why is that? Well, when living in California and flying here for this conference in Washington, D.C., involves going from a 24 hour California day to a 21 hour day on the east coast. The day is essentially shrinking. This is opposite the way the natural 25 hour rhythm of the internal clock wants to go. When returning home from the clock moves from a 24 hour Washington, D.C. day to a 27 hour day back in California (staying up three hours later). Traveling west involves lengthening the 24 hour day in the direction of the internal clock's natural tendency. This is similar to moving a shift schedule from day, to swing, to night. Therefore, it is a physiological reason that traveling west or moving a shift schedule "forward" involves easier physiological adaptation than traveling east or moving a shift schedule "backwards" across the clock. Both the quantity and quality of sleep can be affected

by the direction in which the internal circadian clock is moved. Understanding the basic circadian physiology can help to quantify, in an operational sense, what might be expected in the quantity and quality of sleep obtained during a particular schedule.

Transportation requirements clearly can affect these physiological factors. One consideration is that most transportation operations do not involve a one time occurrence. Individuals cross time zones and return, move to a different work schedule and then rotate again. There can be a continuous disruption of the circadian clock due to these changing requirements.

Another consideration in transportation is that operators can be on duty for extended periods of time. That translates to prolonged wakefulness. As all modes of transportation become more automated, as the technology evolves further, human operators are increasingly put into a passive monitoring role of these automated systems. This reduced role for the human operator raises questions about the potential for boredom and complacency to affect alertness and performance.

There are a variety of signs and symptoms that you might look for in yourself or others when trying to evaluate fatigue. For example, forgetful. When you've had to read that same passage three times, that is a sign that your memory is starting to be affected. Poor decisions, for example, Jim Danaher mentioned an extremely experienced crew making some poor decisions about a landing. Other signs could be slowed reaction time, reduced vigilance or poor communication. In the Guantanamo Bay aviation accident previously described, there were a lot of words spoken by the flight crew if you look at the transcript from the cockpit voice recorder. However, in spite of all these

words, the NTSB pointed out there was poor communication among the crew. Other signs can include fixation, poor mood, and ultimately, actually falling asleep.

These are some of the physiological considerations that underlie fatigue. These basics of sleep and circadian physiology will provide an initial foundation for the information provided in subsequent presentations.



Good Sleep Habits

Dr. Mark R. Rosekind

**Fatigue Countermeasures Program
NASA Ames Research Center**

November 1, 1995 -- Early Afternoon Session



We have a series of three presentations in this session. I have some introductory comments and then we will talk about good sleep habits; Dr. Dinges will discuss napping strategies; and Dr. Roth will speak about alcohol, sleeping medications, and caffeine.

When I think of the NASA approach to managing fatigue, one component has to do with the 24-hour perspective on operational requirements. The other component is the approach to addressing the issue of fatigue. Once people acknowledge that fatigue is an issue and that it deserves attention, then the next request is usually to fix it. Typically the request is for a quick fix, a magic bullet, and that fix should work for everybody. This suggests that the individual does not matter, or the specific operational requirement, or the schedule--just the quick fix. And again, that quick fix should work for everybody.

There is no magic bullet to cure fatigue in transportation operations. Sleep and circadian physiology are complex, and the operational world is also complex with changing demands. It is extremely difficult to identify a magic cure for all transportation-related fatigue. People are different; their jobs are different; there are

varied demands and schedules of operational settings, and a range of other factors that can affect fatigue. Therefore, it is too simplistic to suggest that a magic cure exists or would be effective.

There are a variety of strategies that are offered commercially to cure jet lag. Before using or buying a specific strategy or countermeasure there are several questions that should be considered. First, is there a physiological mechanism that can explain why the countermeasure should work? Are solid scientific data available to demonstrate the countermeasure's effectiveness? Are data available to determine how much to use, when, what should the effect be, and how long it will last? What are the adverse effects? What are the short- and long-term effects? Can the benefits and costs associated with use be determined? These are questions that should be considered before application of any particular strategy in an operational setting.

The complexity of operations and human physiology suggest that at this point in time it would be extremely difficult, if not impossible, to eliminate fatigue in operational settings. Rather than attempt to eliminate fatigue, the challenge is to manage it. Since there is no

magic cure, managing fatigue in transportation will involve examination of each component of the system. Each component should be examined for approaches that maximally incorporate the current scientific knowledge on fatigue. There are at least the following six factors to examine when trying to manage fatigue in operational settings.

The first is education and training. We believe that an educational foundation for anything you want to enact or accomplish in addressing fatigue, whether it be screening or regulations or just a particular personal countermeasure, is critical for people to understand why, and will enhance the effectiveness of any approach.

A second factor is hours of service. These are controlled by everything from Federal regulations, to contracts, to company policies, even industry policies.

A third factor is scheduling practices. You might have the perfect regulations, but scheduling practices could still detrimentally affect sleep and circadian physiology.

A fourth factor is countermeasures. There are a variety of strategies that could be used at the personal or corporate level. Many of the available strategies will be identified in subsequent presentations.

A fifth factor involves design and technology. For example, it was mentioned earlier how a highly automated system can create the potential for boredom and complacency. This raises a question about how to design these automated systems to promote and maintain alertness.

A sixth factor is research. While a large and significant amount of scientific data now exist on fatigue-related issues, there is still much that

is not known. There are some specific operational questions that could be addressed by generalizing from other data sources. There are also issues that deserve particular attention and original research to answer.

We have just moved from the “no magic bullet” to a fairly broad approach to addressing fatigue in transportation. When confronted with such a task, some will believe or say that it can not be done. However, this is not just a conceptual approach. Across modes of transportation there are successful activities in each of these areas occurring right now. You will hear later about education and training. One example in the area of hours of service: the FAA has a program of activities looking at hours of service and working on possible new regulatory approaches. Regarding scheduling practice, there are several different companies in air, trucking, etc. that are incorporating some of these principles. You are going to hear about the countermeasures and the technology in subsequent presentations. Clearly, there is a lot of research currently going on, including by many of the people here in the room today.

Now, what can you actually do about this. Many of the approaches discussed will be represented as recommendations. And again, that is to indicate that there is not a magic bullet, there is no one cure all. They are provided here today as a way for you to think about how to apply them in your domain. It is critical to tailor them your specific individual needs and operational requirements.

It is also important to think about how to utilize these strategies in combinations. Not to use one, but many of them. And one of the ways to think about countermeasures, is to think about preventive strategies versus operational ones.

What are preventive strategies? Things that you use before a duty period or on a rest period that help you reduce the effects of fatigue during the subsequent operation. We differentiate those countermeasures from the operational strategies, those that you use when you are on the job, driving a truck, flying a plane, etc. to help you maintain your alertness and performance during that duty period.

The following are examples of these countermeasures. These initial examples are so general, that they apply to almost everyone whether you are on duty, flying, driving, or any other type of operation.

First some preventive strategies. At home, get the best sleep you can before a trip. There was an interesting study that was done trying to see what factors predicted the severity of jet lag. The number one factor that emerged was how much sleep had been lost just prior to the trip. So when you are home preparing to leave, and focused on accomplishing tasks, it is common to lose sleep. So any time you start a trip, again driving, sailing, flying, etc., and you have a sleep debt already in the red, then all you do is increase your chances of going further in the red or having the operational disruption create more problems. So, we recommend at a minimum try to get two nights of good sleep before you begin a duty period. Try to be well rested. If you are well rested, will that make you invulnerable to subsequent sleep loss or circadian disruption? Not at all. But instead of starting in a negative position, with a sleep debt already in the red, you will be physiologically better prepared to manage subsequent sleep and circadian disruption.

The following strategy also generalizes across all modes of transportation. There are some who feel that when they go on a duty period

they need eight hours of sleep, but could get away with only seven hours of sleep during a trip. Remember that sleep loss builds up. If you need eight hours of sleep, try and get eight hours. The optimum is eight hours consolidated sleep at one time. But if you can only do it in six hours and a two hour nap, do it. There is sort of a priority system. But the key is just do not go into the operation planning to get along with less sleep than you actually need. If you need eight hours try and find a way, even through napping, etc., to get that total sleep for each 24 hour period.

While there can be a discrepancy between what you feel and what your physiology is doing, there are times you can trust your physiology. What does that mean? When you are feeling sleepy and showing signs of sleepiness (like nodding off, eyes closing, etc.) then pay attention to your brain's signal and get some sleep. Pay attention, trust the physiology.

There are also some important good sleep habits that everyone should follow to promote a good quality and quantity of sleep. First, you can train your body that it is time to go to sleep. One way to do this is to create for yourself a pre-bedtime, pre-sleep routine. Create a routine set of signals that tell your body and mind it is time to unwind and prepare for sleep. These cues might include warm milk, reading a book, whatever the routine is that you want to go through, practice it at home. You can then use the same routine and cues when away on a trip and promote sleep.

Try to use the bedroom for sleep and avoid work, worry, exercise, or other activities not conducive to sleep. Again, the bedroom should be a place where you relax and go to sleep. If you use the bed and the bedroom to have fights, or balance your checkbook if it is not in good

shape, or whatever, then the bed and bedroom become associated with being awake and anxious, and not associated with falling asleep.

Sleep time. This is especially important to people that have daytime sleep periods. Try to minimize other responsibilities; you want to keep that designated sleep time sacred. Sometimes this can be difficult, for example if you have young kids, or other kinds of family commitments.

Eating strange foods prior to bed should not give you nightmares. However, it is important that if you are hungry or thirsty, you eat a light snack or have a small amount to drink before bed.

Dr. Roth will talk about caffeine consumption later this afternoon. Operationally when using caffeine to promote wakefulness, you must also consider your ability to get sleep on your next rest period.

It is important that the environment you sleep in is quiet, dark, a comfortable temperature, and secure.

When you get in bed and watch the news, you may shut the television off, but it can be difficult to just shut your brain off and go right to sleep. Again, do not use the bed and bedroom to engage in activities that make you anxious or worried. Do activities that are conducive to sleep.

There are techniques that have been scientifically demonstrated to help you relax your mind and body. A wide range of them exist and they are skills, which means they can be taught, you can learn them, and the more they are practiced, the more expert you become. They have been demonstrated to help people unwind, re-

lax, and get to sleep. These are skills that would always be available to you and you travel with the necessary equipment -- your body, your mind. They may be one of the most underutilized skills available to promote good sleep. You can practice the relaxation skill, become expert at home, and then use it anytime, in any hotel, in any mode of transportation.

Another recommendation is the 30 minute toss and turn limit. You can force yourself to stay awake, up to a point. You can not force yourself to go to sleep. So, if you get into bed, and you can not get to sleep within 30 minutes, do not toss and turn, get out of bed. When you do get out of bed, do something conducive to falling asleep, like a relaxation skill but do not start a 700 page novel or your favorite 2-hour video. I typically recommend reading some government reports or regulations, that should do it for you. Get out of bed when you get sleepy, get back into bed when you're tired and sleepy enough to actually be able to fall asleep.

Many of the strategies that have just been presented are good basic sleep habits, useful for all of us regardless of your situation. You do not have to be a rocket scientist (a) to understand them or (b) to use them. And yet each of us will violate many of these basic tenants every day. These preventive strategies provide an initial step to obtaining good quality and a sufficient quantity of sleep prior to operations.

The next presentation will be on napping strategies provided by Dr. Dave Dinges from the University of Pennsylvania Medical School.



Education and Training Approaches

Dr. Mark R. Rosekind

Fatigue Countermeasures Program NASA Ames Research Center

November 2, 1995 -- Late Afternoon Session #1



Next we will be discussing education and training approaches that are available. This symposium is partially a result of a NASA/FAA education module that was created. I will be talking about other examples of educational programs that are available and also describing resources that you can access to apply the information discussed throughout the day.

The first program to be described actually begins with Dr. John Lauber, who was one of the individuals that began the NASA Ames fatigue/jet lag program in 1980. Dr. Lauber continually emphasized the importance of not conducting research in a vacuum and that worthwhile and useful results should be returned to the operational community.

To meet this challenge, about a year and half ago, the NASA Ames Fatigue Countermeasures Program, in collaboration with the FAA, created an education and training module. The Module is entitled, "Alertness Management in Flight Operations." The Module is a package of information about what has been learned from the general scientific literature, from NASA research, and other resources. The Module is focused on use and distribution

within the aviation industry. The objectives of the Module are: 1) to explain the current state of knowledge about the physiological mechanisms that underlie fatigue, 2) misconceptions, and 3) fatigue countermeasure recommendations. Many of the specific strategy recommendations contained in the Module have been discussed throughout the day.

The Module presentation is divided into three major parts. The first part examines fatigue factors in flight operations, including the physiological considerations described earlier and how operations affect those factors.

The next section is on common misconceptions. Essentially, this is myth busting. There is a lot of information available from a variety of sources, a lot of personal experience, and many anecdotes. In this section, some common misconceptions are addressed using the scientific information provided in the first part of the Module.

The last section presents information on a range of preventive and operational fatigue countermeasures. What are the strategies that people can actually use to try and deal with performance and alertness in real world settings.



A final, important piece of the Module is discussion. We believe that it is important to not only cover the didactic information, but to spend time on concrete examples of how the information is applied. The discussion involves application to the specific requirements of that particular operational environment.

The Module was developed as a one-hour live presentation. This provides an opportunity for interaction, and the discussion focused on application. The live presentation is complemented by a NASA/FAA Technical Memorandum. The publication provides all of the slides from the presentation and supporting text. The intent was that during the presentation, instead of having to write all of the notes down, a participant has a publication with all of the slides. If you are a trainer, then the supporting text provides additional information about the content on each slide.

Dr. John Lauber wrote the preface for the publication and there are appendices on sleep disorders, NASA studies, and other general references, both specific to aviation and also general ones.

The Module was field tested extensively prior to implementation. It was presented about 30 times for several thousand people in a range of different settings so we could incorporate their comments into the final version. The NASA Ames Fatigue Countermeasures Program is a relatively small program, and it was not our intent to go out and be the primary source presenting the Module throughout the aviation industry. Instead, we developed a two-day train-the-trainer workshop. Our hope is to transfer the information in the Module throughout the entire industry. The information in the Module is relevant to anyone in a 24-hour operational settings such as flight crews in avia-

tion, truck drivers, shift workers, flight attendants, medical personnel, regulatory agencies, accident investigators, everyone who confronts the physiological challenges. This information is relevant to schedulers and dispatchers, maintenance personnel, and across the broad spectrum of individuals involved in the transportation industry and other 24-hour settings.

The two-day train-the-trainer workshop is held at NASA Ames Research Center in the San Francisco Bay Area in California. On the first day of the workshop we provide participants with in-depth information about sleep and sleep disorders, circadian rhythms, and performance. On the second day, we provide information obtained from NASA studies, fatigue countermeasures, and provide a presentation of the Module. The intent was for workshop participants to take all of the information and the Module and transfer the information to the aviation industry. This is a NASA/FAA product and there is no cost to attend the workshop except your own travel expenses.

To date, we have held 14 workshops, for 276 participants, from 144 different organizations, from 14 countries. While it seems a daunting task to provide information to an entire transportation industry, this provides a successful model of where to start. This model is not a concept; it is currently in practice. Workshop participants thus far have represented almost every aspect of aviation. They have come from commercial, corporate, regional, general aviation, regulatory people, NTSB people, everyone you could imagine. In fact, one reason we are having this symposium is that Chairman Hall attended one of our education and training workshops in December 1994. Literally by lunch time, he was asking how to transfer the information to other modes of transportation. I would like to personally acknowledge

and thank Chairman Hall for not just asking the question, but acting on it as well. Besides aviation environments, we have also had marine operators, physicians, and law enforcement personnel attending the workshops.

Of course, the bottom line is actually getting the information to the operational community. In a survey of our workshop participants that is almost a year old, we found the NASA/FAA module is in place, functioning, and being presented at 33 organizations. Estimates, provided by the individuals presenting the module at these organizations, suggests that it will reach about 38,000 flight crew and others this year.

One of the first groups that attended our workshop was from American Airlines, and Linda Campbell who is a nurse there, has given the Module 603 times for 6,500 flight crew. There are 10,000 pilots at American Airlines. She has now covered 6,500 of them, and is in the process of extending the Module to the 20,000 flight attendants at American as well. This is just one example of the Module in use now and expanding.

The 33 organizations currently using the Module include many of the major airlines in the United States and it has been transferred internationally to many other organizations. This transfer includes not just air carriers, but also regulatory bodies and accident investigation authorities as well. There are 12 other programs that are currently in development, and these will reach at least another 10,000 individuals. Again, this is not just a concept, these are people using the information internationally throughout the aviation industry.

Participants in our workshop receive in-depth information, the NASA/FAA education and training module, a set of slides, and other re-

source materials that they can take back to their organizations to support implementation of the Module. One of our goals is provide enough information and resources so that participants are comfortable enough to take the Module and determine the format and forum for its use at their organization. We do not tell participants how it has to be used but instead try to support them in their implementation.

There is an important example to highlight how education lays the foundation for a tremendous amount of other activity addressing fatigue. The FAA recently has initiated a working group to develop an advisory circular on fatigue countermeasures that is essentially based on the Module. The intent is to take the information in the Module and make it even more available to flight crews across the country.

There are also other examples of educational activities currently underway within transportation. The following are some examples of these activities and is not intended to be a comprehensive listing. Other resources that are available will be described soon. So, here are a few representative, non-aviation examples of educational efforts focused on managing fatigue in different modes of transportation.

First, the AAA Foundation for Traffic Safety has a large program focused on driver fatigue. They have a great brochure called "Wake Up," and Dave Willis and Stephanie Fall provided some numbers about the distribution of this brochure. They have 1,000,000 brochures that have been printed, 800,000 that have already been sent out to the industry. They have public service announcements that are available. They are talking about an audio tape so you can listen to the information in your car, without falling asleep. One important approach they are using is to package the information

into different formats, from printed material to radio spots to audio tapes.

The National Sleep Foundation, which is now based here in Washington, D.C., has also developed an aggressive program to educate the public and professionals in different modes of transportation and in all areas of our society. They have a program called "Drive Alert, Arrive Alive" and they have now put on this program in five states with four others planned. Their model program is one initiated in New York where they had extensive participation from the Governor's office, different regulatory agencies, educational programs, all wrapped up into an implementation within New York state. These are resources available to anyone interested in obtaining this information.

We had an individual, Mr. Vincent Cantwell, from American Heavy Lift, a marine operator, who attended the NASA education workshop and has now taken the NASA module information and developed it for use in marine transportation environments. Most content in the NASA/FAA Module is generic information but it should be focused on the specifics of your training environment and operational requirements. Vincent incorporated appropriate examples to fit marine operations, translated words and content to fit shipping activities, and added new content that was appropriate to the specific operational requirements of the marine environment. The marine educational module is being field tested at several sites.

Bill Rogers from the American Trucking Association has created a parallel educational module for trucking that is in final stages of development. Again, making changes appropriate to the trucking environment, their operators and other personnel, and the diverse range of operational requirements in trucking.

Another example of transfer is Dr. Melchor Antuñano, director of medical education at the FAA Civil Aeromedical Institute, who has created a Spanish version of the NASA/FAA module, and made it available for use in South America and other places.

Another example is Lt. Colonel Sam Holoviak, Deputy Chairman of the Division of Aerospace Physiology at the School of Aerospace Medicine at Brooks Air Force Base in Texas. They have taken the NASA/FAA module and other Air Force relevant information from their own personnel, like Dr. John French and others, and created a package for aerospace physiology training. The information is in the process of implementation at 21 units and provided to about 13,000 Air Force personnel.

These are representative examples of activities currently underway in different transportation modes to provide educational materials about fatigue and countermeasures. Resources are available to transfer this information to any operational setting. One caveat that I would like to emphasize is that there are efforts to make this information readily available to any interested party, at least at NASA with the NASA/FAA module, we have tried to exert some quality control. That was part of our rationale in developing the training workshop. We bring people in, and if you are interested and motivated enough to participate through the two days of training, all the information is made available to you, and we try to support participants in their subsequent implementation.

There are some general considerations when you consider any kind of educational approach. Again, an educational program can become the knowledge base for a range of other fatigue-related activities. Often it only takes one good

idea and some effort to move an important activity forward. An example is the current FAA activity to develop advisory circular material based on the NASA/FAA education module. This activity was initiated when Al Prest, Vice President of Operations at the Air Transport Association, wrote the FAA and highlighted that the Module was already in existence and suggested creating advisory material that could be distributed by the FAA throughout the entire industry. That is an example of how straight forward it can be to initiate an activity that has potential to educate large segments of an entire mode of transportation. I acknowledge and credit Al Prest for making the suggestion and Anthony Broderick, an Associate Administrator at the FAA, for acting on it.

American Airlines was the first organization to implement the NASA/FAA education module. Eventually, it became a part of required training curriculum. In their classes, many questions were raised about scheduling. In response to those questions, American Airlines created an internal, scheduling working group to determine how to incorporate the physiological information from the Module into their regular scheduling practices. And what they have done, to their credit, is not end up in a contract negotiation, but rather in a working group that addresses these issues very effectively. These are examples of how the information can lead to further activities.

It is important that industry-specific materials be developed. Utilize whatever generic information and materials are available but you must focus educational materials for your particular audience. This is critical if the information is to be accepted and used by the operational community. There are also a diverse range of forums and formats in which to distribute educational materials. For example,

while our education module was developed to be presented in a live format, we are in the process of creating some videos. These videos are intended to focus on particular environments, like short-haul, long-haul, regional flying, overnight cargo, and other specific flight environments. We also intend to create a video of the full Module for environments where the live presentation would be impractical or not available. The AAA Foundation also exemplifies this approach of multiple formats through different mediums. While a one-time educational exposure is a critical first step, you must also find ways to saturate the operating environment to get the information out. Follow-up is important to help support implementation.

And while there is a tremendous amount of information already available and useful to the operational community, it is also clear that there is much more to learn. Once new information becomes available there should be a mechanism to provide updates. This helps to keep the issue visible and highlights new information or countermeasures.



Fatigue Resources Directory

Dr. Mark R. Rosekind

**Fatigue Countermeasures Program
NASA Ames Research Center**

November 1, 1995 -- Late Afternoon Session #2



The last item of the day is to move from educational approaches to a product created specifically for this symposium. You will find it in Appendix H of your binder. The Fatigue Resource Directory was created by the NASA Ames Fatigue Countermeasures Program and the NTSB with support from all of you that provided inputs to the Directory. When discussing the format of this symposium, NTSB/NASA organizers believed the presentations to be the critical educational foundation of today's activities. We also believed that it would be important to provide something concrete, a product that would be available to participants to support the efforts in this area after the symposium. The objective was to provide information and access to fatigue-related resources so that you could take what you had learned today and go home and either as an individual or as an organization, apply it. So NASA and the NTSB created the Fatigue Resource Directory to meet that objective.

First, I would like to thank all of those individuals who submitted entries for this document. Second, I want to also apologize to anyone who is not included but would be interested in having an entry in the Directory. There was no intent to leave anybody out but this was our first effort to produce such a Directory and

have it available at this meeting for you to take home. The Directory is separated into several categories. There are some initial introductory materials, and then sections on countermeasures, government activities, industry activities, and public interest groups. The specific entries provide information on a point of contact, activity sponsors, specifics of the actual activity, and what resources are available. You can scan the Directory and find resources on educational activities. Look in that section, you will find the AAA Foundation, the National Sleep Foundation, and many of the other examples that have been highlighted today. Throughout the day, as you have questioned how to access the individuals, organizations, or information presented, the Fatigue Resource Directory should provide a starting point.

In the section on scientific information, we tried to provide a range of resources. That section includes more details about our distinguished speakers today. My introductory remarks about these individuals were minimal because these more extensive materials about them are available in the Directory. It also provides other resources regarding scientific studies. The scientific resources are available through university libraries and there are other mechanisms for you to be able to access information that is

available. Included in that section is a listing of all the American Sleep Disorders Association (ASDA) accredited sleep disorders clinics in the United States. So when you have questions about sleep apnea and wonder who to call in your local area, the directory is in there. There is also information on how to reach the ASDA for further information about sleep disorder clinics or specialists.

We hope this will not be a static document but rather a dynamic one. Included at the end is a form to provide input to the next iteration or update of the Fatigue Resource Directory. The form requests the same content as is currently in the Directory and is an opportunity to provide new or updated entries. So if you would like to be included in the future, or you have new information to update, please fill in the form and the instructions are on the form about where to send it. At this point, the NASA Ames Fatigue Countermeasures Program is coordinating the Directory, though other Federal agencies have indicated their interest about providing the next update and maintaining it into the future.

The following caveat must be absolutely clear about the contents of the Fatigue Resource Directory -- "This document is intended as a resource directory and was compiled from input from a wide range of sources. The information provided in this Directory has not been evaluated for its accuracy or effectiveness. Therefore, inclusion in this Directory does not imply endorsement by the NTSB or NASA." That is an important caveat, so you know that just because an entry is in the Directory does not mean it has a seal of approval from the NTSB or NASA. It means that information was requested from a wide range of sources, input was provided, we performed a spell check, and standardized the format. However,

that is the extent of oversight and the process did not involve scientific or other reviews of the inputs. There is a wide range of information in the Directory, and it is important for you as a consumer, to be knowledgeable about the many considerations discussed today when using this document.

Another point, which the Fatigue Countermeasures Program is quite proud of is that the Fatigue Resource Directory is available on-line. The NASA Ames Research Center has been identified as the Center of Excellence in Information Systems for NASA. So, we are pleased to provide the address to our home page where you will find the Fatigue Resource Directory on the World Wide Web. The internet address to the NASA Ames Fatigue Countermeasures Program home page is: <http://www-afo.arc.nasa.gov/zteam/>. All of the information in this hard copy edition of the Fatigue Resource Directory is also available on-line. I would like to acknowledge and thank Kevin Gregory, from our NASA group, who worked extremely hard right up through Friday evening before coming to Washington, D.C., to make sure that the Directory would be available and on-line at the time of this symposium. So let us know how it looks when you explore the site. The internet address is also listed in the introductory pages of the hard copy version of the Directory.

There are two other points about materials that will be available to you after the symposium. First, everyone who has attended the symposium will be receiving the proceedings. The proceedings will include the basics of the presentations provided throughout the day, and what we hope will be the concrete products from the working group activities tomorrow. Second, a video tape has been made and when you get your proceedings in the mail, it will

include information on how to obtain this video tape. The video will be made available at cost to people interested.

In the front of your binder there is a listing of all the speakers today, that includes everyone from the NTSB, the speakers during the day, and also the Secretary of Transportation who will be addressing the symposium tomorrow morning. The list provides information on how to reach these individuals.

I have some last comments before beginning the question and answer period. I would like us to acknowledge and thank a variety of people who have worked very hard to make this symposium a reality. First, my thanks to Dr. Pack, Dr. Roth, Dr. Czeisler, and Dr. Dinges. They have been most understanding of my persistence to make their presentations operationally focused and relevant, so if you will join me in acknowledging what a superb job they did throughout the day. Thank you for the excellent presentations.

I also want to acknowledge the NTSB. Chairman Hall truly was the driving force to initiate and make this event happen. Julie Beal, Director of Public Affairs at NTSB, and chair of the symposium steering committee at the NTSB, has been tremendous in her tireless efforts dealing with all aspects of this entire event. Charlotte Casey and Nancy Hill have interacted extensively with our NASA program and they have been just superb in their efforts prior to the symposium and onsite. I want to acknowledge that the NTSB had a steering committee, many of the people you will be meeting tomorrow in the working groups, but I would like to acknowledge them, as well as the many other NTSB individuals who made significant contributions to the symposium.

Finally, I would like to acknowledge and thank the NASA Ames Fatigue Countermeasures Program, also known as the Z Team. A sticker with our Z Team logo is provided in your binder. Three Z Team members are here: Donna Miller, Kevin Gregory, and Lissa Webbon. Lissa has sore fingers because she was the one responsible for helping create the Fatigue Resource Directory in a relatively short time. Kevin got everything on-line. Donna does everything else. All three of these people made important contributions to this symposium as part of the NASA team. Roy Smith, Liz Co, Julie Johnson, Ray Oyung, and Dr. Philippa Gander are not here but are literally holding down the fort and continue to build those scientific rockets at NASA Ames. Finally, I would like to acknowledge all the individuals who behind the scenes have been critical to creating this symposium.



Performance Effects of Fatigue*

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November 1, 1995 -- Morning Session



Across many industries, unintentional human performance errors, especially errors of inattention, are the most frequently identified root causes of accidents. This applies to all modes of transportation, where the vulnerability to human error poses special challenges due to both the escalating number of transport operations--many of which involve 24-hour operations--and the growing potential for catastrophe following a human error (e.g., hazmat accidents). This paper provides an overview of the effects of fatigue/sleepiness on performance in persons who are healthy, with special relevance to transportation. More extensive discussions of these issues can be found in other recent articles (Dinges & Kribbs, 1991; Dinges, 1992; Dinges, 1995).

1. Fatigue originates in biology and erodes performance.

Fatigue-related performance impairment should be a concern in all modes of transportation, because the factors that produce fatigue, and the factors that potentiate or unmask it, are present throughout many transportation operations. Extensive scientific research in the past 40 years has firmly established that fatigue has its basis in the combined interaction of the cir-

cadian rhythm in alertness/sleepiness and the effects of inadequate sleep. Once the biological pressure for sleepiness is present in a person, it can be potentiated or unmasked by tasks that require relatively passive vigilance. Sustained attention is a key performance demand in virtually all modes of modern transportation, and it has increased in direct proportion to the use of automation in transportation systems. This phenomenon is amply illustrated in the modern automobile in which cruise control, eight-way adjustable seats, stereo sound, and climate controls create an environment that requires little more than a finger on the wheel and sustained attention.

Toss of alertness from fatigue has specific, identifiable determinants, and specific, deleterious effects on performance. Changes in brain function--often brief and uncontrollable--form the basis for the performance deficits resulting

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from fatigue/sleepiness. Early in the history of research in sleep deprivation it was discovered that changes in brain waves (EEG) were associated with the more serious failures of performance. In other words, the brain appears to be “microsleeping” during performance lapses (“lapses” refer to periods of performance in which a response is not given when it should have been, or it is given quite late relative to the stimulus). As sleepiness increases, so also do microsleeps and performance lapses. In other words, as fatigue increases, the brain appears to fall asleep involuntarily, against the will of the operator, especially (but not exclusively) when the performance demands involve sustained attention and monotony. As important as it is to recognize that the effects of fatigue on performance are based in changes in brain function, it is equally important to note that fatigue is not caused by or prevented by any known characteristics of personality, intelligence, education, training, skill, compensation, motivation, physical size, strength, attractiveness or professionalism. A common myth is that some or all of the latter factors will prevent fatigue-related performance failures. Certainly being educated about fatigue and how it expresses in performance may help you guard against it or recognize it when it occurs. But the fundamental problem of what causes the brain to fatigue and performance to fail is not lack of physical strength, or lack of intelligence, or lack of professionalism. Rather, it is a neurobiological process directly related to the circadian pacemaker in the brain and to the biological sleep need of the individual.

Four processes are considered relevant to fatigue-related changes in alertness and performance. The first is the circadian phase of the biological clock in the brain; the second and third have to do with acute and cumulative sleep loss, respectively; and the fourth involves

the awakening process (sleep inertia). Each of these factors can produce performance failures, especially lapses (also referred to as gaps, pauses, or blocks), which as noted above, involve a failure to respond, or a failure to respond in a timely manner. Lapses are typically a half second to 10 seconds in duration, but this brevity hides the fundamental risk they pose to safety in transportation operations. For example, during a one-second lapse caused by the brain is microsleeping, a motor vehicle traveling at 60 m.p.h. covers 88 feet (or 5 car lengths); a train travelling at 120 m.p.h. moves 176 feet; a plane flying at 250 knots travels more than 370 feet. Thus, the distance covered during even a brief lapse is easily enough to make it impossible to avoid a collision if a sudden action is required.

Biological time of day and lapses. Controlled laboratory studies have demonstrated that each of the determinants of fatigue will increase the tendency of an operator to experience involuntary lapses. In general an individual's circadian pacemaker (or biological time of day) opposes sleepiness during the day, but not at night (especially not between the hours of midnight and eight a.m.). Consequently, when an attempt is made to reverse this circadian rhythm in alertness, by working at night, lapses increase two- to ten-fold (during performance on a 10-minute vigilance task) across the period of night work during which sleep normally occurs, and they follow a profile similar to the major physiological marker of circadian phase (core body temperature).

Acute wake duration and lapses. The longer one is awake without any sleep beyond the normal waking day of 14-16 hours, the greater the occurrence of lapses, and the longer they become in duration. For example, there is a four- to ten-fold increase in lapsing on a brief vigi-

lance task between the hours of 10 a.m. and 10 p.m. after a night without sleep.

Chronic undersleeping and lapses. Fatigue can also affect performance through chronic undersleeping. This refers to sleeping less each day than one's biological need for sleep. It can lead to *cumulative sleep debt*, which can produce a cumulative increase in lapses, even during the daytime. Recent evidence from a study we performed on the effects of four to five hours of sleep each night for seven consecutive nights revealed that lapses on a brief vigilance task performed between 10 a.m. and 10 p.m. increased three- to five-fold, and were still increasing when the sleep restriction phase ended. Such data suggest that chronic undersleeping results in a performance deficit separate from that associated with the circadian pacemaker and with acute wakefulness.

Sleep inertia and lapses. The fourth category of fatigue-related performance impairment results from something called "sleep inertia," which refers to a difficulty achieving full, waking alertness after sleep. Alertness and performance are usually reduced upon awakening from sleep. Lapses increase during sleep inertia, especially if the sleep is very deep (as measured by intense slow wave sleep), and the awakening from sleep is abrupt. Unlike diminished performance capacity due to circadian rhythms, acute wakefulness, and chronic undersleeping, sleep inertia often can be reversed within 10-20 minutes, by activity and noise.

2. Fatigue results in a range of performance deficits.

Although lapses are a hallmark of fatigued performance and they increase in frequency and duration with each of the major determinants of fatigue described above, sleep loss and circadian rhythms also lead to negative effects in other areas of performance. There a number of basic categories of performance output that are affected by fatigue, regardless of the biological factors that produced the fatigue/sleepiness.

Fatigue increases performance variability. As sleepiness develops, performance becomes more variable. This variability is in part due to an increase in lapses (errors of omission), as described above. When not fatigued the performer is usually correct and timely in responding. As fatigue develops and worsens, performance begins to be intermittently incorrect and often untimely. This increased variability due to lapsing, especially in tasks that require sustained attention, makes performance unreliable in a fatigued person through promotion of unpredictable performance failures (e.g., missed signals). Often, a fatigued operator's reaction to lapsing and performance variability is to increase motivation and compensatory effort--it is this increasing effort needed when fatigued that prompts some persons to report that their work is both tiring and stressful. Increased motivation and compensatory effort can constraint fatigue-related performance failures, but the effect is usually short-lived and ultimately fails to prevent either lapses or highly variable performance in sleep-deprived subjects. Work contexts that involve physical passivity and sustained monitoring are especially likely to permit lapses to occur if biological pressure for sleep is present. The more automated the transportation system and the more a fatigued individual is left alone in such a system, the more

variability, lapsing, and unpredictability will characterize performance.

Fatigue slows reactions. Both the speed of physical reaction times and the speed of thought processes are slowed as fatigue increases during biological night and/or after sleep loss. Such slowing can happen even when lapsing is not occurring. The very fastest physical reaction times of a fatigued operator can slow by 5-25%. The slowing of cognitive reactions (i.e., thought processes) is generally associated with a compensatory effort on the part of the fatigued operator to remain accurate (i.e., the speed-accuracy tradeoff). Slowed reactions clearly have practical implications. They can be costly if responses are supposed to be fast in an effort to avoid a collision or to monitor a critical piece of information (e.g., signal) in order to know when to make a turn or stop.

Fatigue increases errors. Performance is generally characterized by few errors and sustained motivation to avoid errors when an operator is not fatigued. As fatigue increases, however, there is a tendency to make mental mistakes and to persevere on ineffective solutions. The latter refers to a tired operator attempting to solve a novel problem with the same old solution used in the past. Certainly this can occur for other reasons as well, but when fatigued, people seem to fail to appreciate that their logic and judgment may be flawed, and they will waste potentially critical time and resources pursuing an ineffective strategy. In this sense, fatigue appears to limit an operator's range of options. It also explicitly increases errors (of omission and commission) and the compensatory effort needed to avoid them, while at the same time it can lead to a decrease in concern about making errors. This latter effect is very serious in many modern transportation systems, which are quite forgiving of certain kinds of

errors at certain times (e.g., during the cruise portion of a flight), but not at other times (e.g., on approach to landing or during takeoff). Consequently, in many technology-rich transportation environments, there are periods when performance errors due to fatigue can occur with few serious consequences, leaving the false impression that there is no real cost to operating when fatigued. This is clearly an inflated sense of security.

Fatigue increases false responding. False responses (i.e., responding when no stimulus is present) are relatively rare when a person is not fatigued, but they can increase as an operator attempts to maintain performance in the face of increased lapsing from fatigue. They are most likely to occur in situations involving a tired operator who becomes aware that he/she is missing key signals. After a lapse, an operator will begin to anticipate the signal's presence, and this can lead to increased false responses. In this sense, false responses reflect a compensatory effort to improve performance. This overemphasis that the fatigued operator places on one type of signal or piece of information can limit the operator's appreciation of other task-relevant information, which in turn can limit situational awareness.

Fatigue increases memory errors. Sleep loss also results in increased errors of short-term memory. Depending on the fatigue level, a tired operator can have difficulty recalling what was seen, read, or heard. This can result in failure to recall critical information, and uncertainty about the status of the operational situation.

Fatigue leads to vigilance decrement. When an operator is not fatigued from night work and sleep loss, within a reasonable work period duration, there is little deterioration in performance as a function of time-on-task. When fa-

tigued, however, an operator may begin a monitoring task with good performance, but even relatively short work periods can be associated with a marked decrement of performance as a function of time-on-task. In other words, while both fatigued and non-fatigued operators may begin a task at the same excellent level of performance, the vigilance of the fatigued operator will deteriorate as time passes relative to the non-fatigued operator. Consequently, beginning a task proficiently, especially an attention-rich monitoring task, can give the false impression that a fatigued operator will be safe later on. Therefore, when judging the performance capability of the fatigued operator, it is unwise to rely on initially good performance as evidence that the operator will be safe 30 minutes to 8 hours later. The question is not how well is the operator performing in terms of sustained attention and ability to process information early in the work period, but rather, how safe is performance likely to be later in the work period? During biological night and after sleep loss, fatigue will make it exceedingly difficult to sustain performance. The practical implication of this inability to sustain performance with time-on-task is that performance capability can be overestimated.

This overestimation is especially likely to occur when the fatigued operator is asked about his/her level of fatigue and ability to perform prior to beginning work. The mere act of asking for this assessment can promote transient alertness (from the social interaction and significance of the question) and this brief arousal can make the fatigued operator decide he/she is fit and without performance decrement. However, depending on the magnitude of the underlying pressure for sleep, the operator can begin to experience lapses, microsleeps, slowed reactions, forgetfulness, and a marked vigilance decrement soon after beginning the task. This

is one reason why people can be inaccurate judges of their biological pressure for fatigue and their vulnerability to fatigue-related performance decrements.

Fatigue leads to reduced motivation and laxity. In addition to performance deficits fatigue can result in lowered motivation to perform well. This can translate into a willingness to take risks and a laxity in safety (e.g., fatigued operator who speeds to end the trip sooner because he/she is tired).

In summary, performance of an individual fatigued by circadian and/or sleep loss factors is characterized by increased variability, lapsing, slowed reactions, errors, false responses, forgetfulness, vigilance decrements, and at times, reduced motivation and laxity in safety. From an operational perspective, deterioration in these basic parameters leads to compromised attention and vigilance, limited situational awareness, and judgement processes clouded by a failure to be able to reliably detect, appreciate, and respond to events in a timely manner.

3. Fatigue affects everyone, but the magnitude of the effect can vary.

The effects of fatigue/sleepiness on performance are the same in all operators, but the magnitude of the effects can vary as a function of a number of factors. In general, persons with sleep disorders, especially disorders that produce excessive sleepiness (e.g., sleep apnea) will experience performance deficits. Among healthy persons, everyone will eventually suffer marked performance deficits (1) when acute sleep loss is sustained (especially beyond 36 hours); (2) when sleep is chronically too short (especially less than four hours per day for mul-

multiple days); and (3) when work is performed at a time of coincidence between sleep deprivation and an individual's biological night. However, when the determinants of fatigue are less severe (e.g., during night shift work or sleep restriction for a day), individual reactions can vary markedly. It appears that in reaction to a single night of night work, perhaps half of all healthy adults who remain motivated can continue to perform reasonably well, assuming only an acute exposure and mild sleep loss. Another third of the population has a moderate level of performance deficit from this kind of exposure. The remaining 10-15%, however, have a severe performance deficit. The reasons for this latter group showing vulnerability to even mild acute fatigue are not yet known. Finally, even among those who experience mild performance deficits, sleepiness can wax and wane, and there can be periods of time in which they experience greater difficulty sustaining attention.

In summary, performance effects of fatigue have their bases in changes in brain function. This basic biological vulnerability to error is not overcome in any permanent way by personality, intelligence, education, training, skill, money, motivation, physical strength, attractiveness, or professionalism. There is no substitute for sleep. Transportation industries that increasingly rely on operators performing tasks 24 hours a day (especially vigilance-based tasks with high-consequence outcomes), should confront the challenges that biological limits placed on operators by the sleep and circadian systems. Research is ongoing to find ways to prevent the performance impairments from fatigue. Given the extensive scientific database on sleep and circadian factors that produce performance changes, and the nature of these changes, it is time to address the potential role of fatigue in transportation catastrophes involv-

ing human error, and to begin work on prevention of such catastrophes in the 24-hour operations of transportation industries.

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Napping Strategies*

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Napping to cope with fatigue has a very special place in the countermeasure arena, because napping has been one of the most carefully studied behavioral strategies for preventing the effects of fatigue on alertness and performance. During the past 15 years, there has been extensive scientific documentation in both academic and field settings of the benefits of naps in persons undergoing prolonged, irregular, and/or sustained work schedules. More extensive discussions of these issues can be found in other recent publications (Dinges & Broughton, 1989; Dinges, 1992; Rosekind et al., 1994; Rosekind et al., 1995).

1. Operational definition of a nap: What napping is and what it is not.

Napping can mean different things, but the definition that best captures the type of "nap" that has been scientifically demonstrated to promote alertness is the following: A nap is physiological sleep of a duration less than or equal to half that of the typical major daily sleep episode of a person. In other words, by this definition, a person who sleeps eight hours a night, is napping whenever the sleep duration is four or fewer hours, regardless of the time of day the sleep is obtained. This definition also comes close to the colloquial meaning of a nap as a

short period of sleep. It is important to appreciate, however, that the definition explicitly also requires that the nap involve "physiological sleep" of the same kind that defines the primary sleep period, including the standardized stages of sleep as reflected in brain activity (EEG) and behavior. In other words, there is no evidence that resting without sleep for the same period of time as a nap will reverse sleepiness and promote alertness in an operator fatigued from sleep deprivation, no matter how physically restful the rest period may be. Consequently, there is no scientific evidence for promotional claims that certain types of napping ("power" napping?) afford extraordinary recuperation because they involve special brain waves without physiological sleep. There is no substitute for sleep, and napping simply involves shorter periods of sleep. Nap sleep is regulated by the same circadian and sleep biological processes that regulate longer sleep

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periods. In summary, napping is not resting without sleep; napping is not physiologically different from sleep; napping is not a substitute for fulfilling the major need for sleep; and napping is not, therefore, a panacea for fatigue, which means it is not the only countermeasure and should not be employed as the only countermeasure in a comprehensive fatigue management strategy.

2. Napping as a voluntary countermeasure strategy.

Napping can be either *voluntary* or *involuntary* (e.g., falling asleep when the intention was to remain awake). Involuntary naps often reflect fatigue and uncontrollable sleepiness, and usually they are considered at best to be inappropriate, and at worst to be dangerous, when they occur in the work place. Voluntary naps, on the other hand, are deliberately taken to discharge fatigue/sleepiness, and these have been the focus of napping as a strategic countermeasure. It is sometimes difficult to get people to take seriously the idea that voluntary planned napping during a work cycle can be beneficial. This is primarily because many people in industrialized societies identify sleeping on the job as reflecting a lack of responsibility. This attitude is captured in phrases like “caught napping,” which refers to an individual’s negligence regarding what they should have been attending to. While involuntary naps may fit this negative image (despite being caused by legitimate biological forces), voluntary naps do not deserve this negative image or bias.

The major point to keep in mind is that in work systems in which people are expected to be awake when their biological clock is promoting sleep/sleepiness, and/or when they are sleep deprived, planned napping as a fatigue coun-

termeasure may be one way in which fatigue-related performance deficits can be reduced. For this technique to be effective, however, napping strategies have to become part of the proactive planning of work activity.

Just like the tendency to feel fatigued/sleepy, the tendency to nap is regulated by two basic neurobiological processes: (1) the internal circadian pacemaker (biological clock), and (2) the homeostatic need for sleep. Evidence for the first regulatory influence comes from the fact that napping is more likely to occur at certain times of the 24-hour day, especially during the usual nocturnal sleep period (e.g., 12 a.m. to 8 a.m.) and during the midday siesta time (e.g., 1 p.m. to 4 p.m.). There is solid evidence from laboratory studies using the multiple sleep latency test and field studies of performance and fatigue-related errors, that the midday peak in sleepiness/napping tendency is reliable, especially if nocturnal sleep is shortened.

Evidence for the second regulatory influence on napping (sleep need) comes from the fact that sleep loss (whether acute or chronic) increases the likelihood for napping at all circadian times, if the sleep need is great enough. This is the case for virtually all healthy adults, even those who predict that they will not be able to nap. If the pressure for sleep is high enough, virtually anyone can take a nap. This fact makes it possible to plan napping as part of a more comprehensive fatigue-countermeasure program in persons who will be exposed to night work and sleep loss.

3. Napping environment.

In order to make napping a practical fatigue countermeasure, it is necessary to know in what

kind of environment the operator will be asked to nap, and what the effects are of certain environmental factors on napping ability. Although there has not been extensive research on all the environmental factors that can influence napping, there are data on the environmental factors that affect sleep in general. To achieve physiological sleep that is continuous (i.e., not fragmented) and therefore likely to reduce sleepiness and promote alertness, naps should be taken in the same kind of environment in which healthy nocturnal sleep is usually taken. This means that when possible, the nap environment should be free of disruptive noise and vibration, it should not be too hot or too cold, it should be safe, and the sleep surface should not be uncomfortable. There is also evidence indicating that nap sleep is less fragmented if the napper is allowed to lie down, rather than merely sitting semi-recumbent. One study showed that the quality of sleep begins to erode when the angle of recline is less than 45° from vertical. This does not mean that a nap in a comfortable reclining chair cannot be beneficial in terms of promoting alertness--the benefits of a nap in a cockpit seat were demonstrated in the studies of planned napping performed by NASA (Rosekind et al., 1994). However, if the napping environment is so hostile that it severely fragments sleep (e.g., arouses the sleeper every minute), then the potential of the nap to ward off fatigue/sleepiness will be markedly reduced.

4. Nap duration.

What duration does a nap have to be to provide of some measurable degree of recovery from fatigue? Many studies show that naps of durations between one hour and three hours markedly improve alertness and performance. However, there is also evidence that naps in-

volving sleep durations under one hour (e.g., 20 - 45 minutes) can promote alertness. In general, the longer the nap, the greater the improvement in objective indices of alertness and performance. But this relationship is not entirely linear. The greatest gain in alertness appears to be derived from the first hour of sleep (relative to subsequent hours), and it is this nonlinearity that probably accounts for the apparently disproportionate benefits of naps in terms of recovery from sleepiness. However, this does not mean that short naps will necessarily result in full recovery of alertness, or that their benefits will be long lasting. Whether the latter occur depends on how fatigued/sleepy the napper was prior to the nap, which is a direct function of the individual's pre-nap sleep debt. For example, if a person is severely sleep deprived (from acute or cumulative sleep loss), a two-hr nap will substantially improve performance, but it will not necessarily return it to baseline/optimal levels. This is one reason why napping is not a substitute for full recovery sleep. However, if the person is fatigued from mild to moderate sleep loss or night work, a nap of 20 minutes to two hours (depending on the opportunity and expected post-nap work duration) can promote alertness and performance levels close to baseline levels. The duration of the post-nap enhanced alertness can vary between one and 12 hours, depending on sleep debt and nap duration. Again, if the sleep debt of the napper is high, then the magnitude and duration of the benefits for alertness and performance will be reduced. When the sleep debt is less severe, even a 25-minute nap can promote alertness and performance to near baseline levels for up to six hours post-nap. Consequently, using napping as a strategy for coping with operationally-induced fatigue requires an appreciation of the factors that will influence the potential of a nap for reducing fatigue. Again, napping can help significantly,

but it is not a definitive solution for fatigue, and it should not be used to the exclusion of longer periods of recovery sleep.

5. Napping and sleep inertia.

It is important to recognize that napping can have positive benefits for helping to manage fatigue, but that these advantages are not realized until a significant negative effect of napping on performance is dissipated. This adverse effect is called sleep inertia, which refers to a difficulty achieving full, waking alertness after sleep. Alertness and performance are usually reduced upon awakening from sleep. This sleep inertia effect often can be reversed within 15 minutes by activity and noise. However, sleep inertia can be severe and longer lasting if the nap is taken by someone with a severe pre-nap sleep debt. This is another reason why it is best to use napping as a strategic countermeasure to prevent severe sleep debt (i.e., napping in advance of significant accumulation of fatigue).

6. Napping in advance of fatigue.

Naps appear to be maximally useful as a fatigue countermeasure strategy when they are taken in advance of, or early on during work performed at night, or during work periods that will ultimately lead to significant sleep debt. Evidence for this idea first came from studies by our laboratory on a concept we called “prophylactic napping,” which refers to using naps as a kind of preemptive strike against cumulative fatigue. Prophylactic napping was intended to prevent some or all of the fatigue-related deficits in performance in persons who had to work for prolonged periods, who had to work at night, and who were going to develop

sleep debts. To test it we compared the effects of naps taken before sleep loss and/or during the first night of work, to the effects of naps taken after sleep loss (both day and night). While all naps helped reduce fatigue and improve performance, the ones taken in advance of sleep loss and/or during the first night’s work provided the greatest gains in terms of both the magnitude and duration of performance improvement, despite the fact that they were of shorter duration than the naps taken after significant sleep debts had developed.

Subsequent studies confirmed the benefits of prophylactic napping.

The laboratory research documenting the benefits of prophylactic napping is conceptually very close to the NASA/FAA study on the effects of “planned cockpit rest” (which was actually planned napping) in long-haul flight crews. In this important field experiment, crews were randomly assigned either to a control (no nap) condition or to a nap condition. Those in the nap condition were afforded a single planned 40-minute nap opportunity in the cockpit seat during each of four 9-12 hour flights, while the other two flight crew members operated the aircraft. The results from this experiment clearly demonstrated that a single nap (mean of 25 minutes sleep) taken by a flight crew member could markedly enhance the crew member’s physiological alertness and psychomotor vigilance performance near the end of flight, when crews must be maximally alert (Rosekind et al., 1994). This study also demonstrated five other fundamentally important points about using planned napping as a fatigue countermeasure strategy: (1) It was possible to safely and effectively plan ahead of time for when a nap would be taken during a work period, rather than waiting until an operator was so tired that microsleeps and involuntary nap-

ping were occurring; (2) it was possible for virtually every operator (90%+) to fall asleep in a reasonable period of time (i.e., 5-10 minutes) during planned naps taken both in the daytime and at night; (3) sleep inertia did not pose a serious problem because 20 minutes was allowed for its dissipation prior to assuming duties; (4) as in laboratory studies, the nap improved objective measures of alertness (i.e., brain activity and probed performance) in flightcrews, but it did not eliminate their feelings of fatigue; and (5) the beneficial effects of a single nap were most evident on night flights, when control crews showed increasing fatigue relative to crews allowed a nap. This study clearly established the practical and safe utilization of napping as a fatigue countermeasure in a real-world operational setting.

7. Napping as a fatigue-countermeasure strategy: Good news and bad news.

As discussed above, there is ample scientific evidence that napping can acutely improve alertness on the job, and that napping in advance of the development of fatigue may offer the greatest benefits in terms of alertness and performance. While short naps can be beneficial, longer naps offer even more recovery, but as nap duration lengthens to an hour or more sleep, sleep inertia will worsen, and consequently, it will require more time to become fully awake and alert post-nap. Napping is not a solution to every fatigue problem engendered by work schedules and operations. It is a limited fatigue countermeasure that can be of considerable benefit if used properly, and if its limitations are recognized. These limitations include the fact that napping may not improve feelings of fatigue; napping requires dissipation of sleep inertia to be beneficial; napping will not promote circadian adjustment to night

work; and napping does not significantly repay cumulative sleep debt. Rather, when used properly, napping is a stop-gap fatigue countermeasure that can promote alertness for limited periods of time in persons who must be exposed to work conditions that engender fatigue.

The good news is that napping, especially in advance of sleep loss and night work, can enhance physiological alertness and performance, depending on the nap sleep quality and duration. Viewed from this perspective, napping as a fatigue countermeasure strategy offers significant advantages in operations that otherwise rely purely on motivation and mental toughness to maintain alertness and performance during night work and sleep loss.

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Technology / Scheduling Approaches

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This article discusses some of the major issues regarding the challenges of establishing standards for the burgeoning growth industry in technological approaches to fatigue management in transportation, and developing work schedules that minimize fatigue yet permit economic viability. More extensive discussions of these issues can be found in other recent articles (Gilliland & Schlegel, 1993; Dinges, 1995).

1. Challenges facing technology for fatigue management.

Virtually all of the technologies being proposed to manage fatigue in transportation are still at the conceptual, prototype, or early testing stages and consequently, their full effectiveness, implementation, and practicality remain unproven. Moreover, because many of them are being developed in a proprietary context, it is not possible to review whether they meet the scientific standards of reliability and validity (including sensitivity and specificity). Generic categories of these technologies include, but are not limited to, the following: (1) computer algorithms for designing work schedules; (2) readiness-to-perform and fitness-for-duty testing modules; (3) personal fatigue

monitors; (4) vehicle-based driving performance monitors; (5) vehicle-based driver alertness/drowsiness monitors; and (6) both low- and high-technology crash avoidance systems.

No one specific technology development will be singled out for praise or criticism in the review. Rather, the classes of technology for fatigue management will be broadly discussed, and the emphasis will be on the need to maintain standards by which technologies are evaluated. One aspect of standards is the feasibility or implementation of a technology. In some areas you find an obsessional concern for implementation realities, with little regard for validity and reliability of fatigue detection. Certainly, implementation of a technology to prevent or identify a fatigued operator is critically important. There is little point to inventing something that has scientific validity that

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cannot be implemented (i.e., it fits perfectly inside a vehicle, but in fact does not measure fatigue or prevent fatigue-related performance failures). On the other hand, excessive concern for implementation without comparable concern about the scientific validity and reliability of a technology is equally inappropriate. In fact, implementation concerns should come after scientific validity and reliability have been established. In terms of the utility of technological approaches for fatigue management, it is fundamentally critical that these approaches be held to acceptable scientific standards. For example, in terms of devices that purport to detect a fatigued operator, basic data must be provided on whether the device detects what it alleges to detect (this is the validity standard), and whether it can detect it repeatedly (this is the reliability standard). Even if a device is reliable and valid, to be practically useful, it must meet additional standards of high sensitivity and high specificity. Thus, the device must detect all (or nearly all) fatigued operators (i.e., high sensitivity standard), without too many false detections (i.e., high specificity standard). A device that has high sensitivity but low specificity will detect fatigue, but may give too many false alarms to be useful. In contrast, a device with low sensitivity but high specificity will give few false alarms, but it may miss too many fatigue events to be useful.

There are also a number of ethical and legal issues that must be confronted if fatigue detection technology is to be located in the workplace. One of these issues concerns who has control over the detection technology. Another concerns the privacy rights of the individual being monitored, and the confidentiality issues of the information acquired. Related to the confidentiality question, are issues of enforcement and use of punitive contingencies when fatigue is detected. For example, from an enforcement

perspective, should fatigue be viewed in the same way impairment from alcohol and drugs are viewed? What role should fatigue monitoring/detection have in assessing regulatory compliance versus providing feedback and/or education to an operator? What are the practices and policies for repeated detection of fatigue in an operator? If fatigue detection is involuntary and subject to enforcement contingencies, will operators accept it or seek to disable it? The answers to these questions are not obvious. Public policy discussion of these issues should begin now, while different technologies for fatigue detection in all modes of transportation are being developed, to allow ethical and legal policy to guide integration of the use of these technologies.

2. Operator, system, and environmentally oriented technologies.

Reviewing the different categories of technologies being proposed for management of fatigue/sleepiness in transportation modes necessarily requires some categorizations. Technologies can be arbitrarily grouped by different criteria, but at least three broad categories of fatigue-related technologies (for detection and/or prevention) include: operator centered technologies, system centered technologies, and environmentally oriented technologies. Space limitations preclude an exhaustive review of each of these categories.

System-centered technologies. These include technologies that monitor the activity (behavior) of the truck, bus, train, plane, ship, etc. Typically system-oriented technologies are designed to detect hardware performance or vehicle-environment interaction that exceed some specified profile and/or algorithm for safe operation. An example of system-oriented fatigue

technology would be a vehicle-based driver monitoring algorithm for detection of unsafe driving performance. The input to such a system is vehicle performance, not driver physiology or behavior. The latter fall under the category of operator-centered technologies. System-centered technologies that help detect unsafe driving associated with impairment (from fatigue or any other source), will likely come to fruition in the motor vehicle area in the next 10 years.

Operator-centered technologies. These include a wide range of approaches to detecting fatigue and performance impairment. They range from assessment of performance capability prior to job engagement (e.g., readiness to perform and fitness for duty testing), to monitoring sources of fatigue (e.g., hours awake, biological time of day), to probing function during work (e.g., trace or secondary tasks), to on-line monitoring of physiology and/or behavior during work (e.g., eye blinks, gaze). There are challenges that the technological initiatives in each of these areas must meet before becoming useful measures of fatigue.

There are a large number of performance test batteries touted as candidates for readiness to perform testing (and/or fitness for duty testing). Unfortunately, many of them are aptitude and language-skill sensitive, and they almost all have rather dramatic learning curves, making them less than ideal candidates for repeated usage in a diverse population. In addition, many have not been validated to be sensitive to fatigue, are not predicated on a model of human performance failure, and do not provide criteria by which to determine when someone is dysfunctional. On the other hand, there is at least one simple performance test system that we have studied (i.e., psychomotor vigilance testing) that does not have some of the apti-

tude- and language-sensitive problems of other tests, and that has been validated to be sensitive to sleep loss and circadian variation, suggesting that there is potential for this approach, both as a readiness to perform test and a way of probing functional capability while on the job. Performance testing is one of the easiest areas to create a technology, and it will therefore likely be one avenue by which fatigue management is undertaken in transportation modes.

Another subclass of operator-centered technology includes those devices that seek to monitor *sources of fatigue*, such as how much sleep an operator has obtained or the operator's biological phase of alertness/sleepiness. Such information is then used to predict when future periods of increased fatigue/sleepiness will occur. To do this, a monitor will have to be predicated on a biomathematical model of human alertness. Interestingly, electronic miniaturization has increasingly made it possible to unobtrusively monitor sleep/wake cycles, making this approach increasingly likely. However, much more work is still needed in predicting when an operator will be fatigued, and more precisely when the fatigue level is most likely to be associated with unsafe operation.

Another area currently receiving much attention in terms of the development of technologies is that of biobehavioral monitoring of an operator's fatigue. Examples of proposed portable measures include brain waves (EEG), eye blinks (number, speed, duration), eye closures, eye movements, direction of gaze, facial characteristics, pupilometric responses, heart rate, electrodermal responses, and body movement. Some of these techniques have been validated to be sensitive to fatigue (e.g., some aspects of EEG signals) but have not yet been made totally practical, while other measurements (e.g.,

facial characteristics) have not yet been validated. As importantly, few of these measures have validated algorithms for *interpreting* the information acquired, even when they acquire fatigue-related information. Finally, even among those biobehavioral measures that have been validated to be sensitive to fatigue, and for which algorithms exist that meaningfully integrate and interpret the information acquired on-line, there are only limited data on their practicality.

Many devices must acquire, interpret, and feedback information in real world contexts. Consequently; a demonstration that a biobehavioral measure can detect fatigue in a controlled measurement context of a laboratory does not ensure that the device will work as well in a real world scenario, where an operator can be active. There is, therefore, still a great deal of progress required in the area of biobehavioral monitoring of fatigue, and in the area of on-board fatigue countermeasures. In the latter area, there are an equally large number of claims of efficacy that have not been demonstrated (at least not in the public domain) to be scientifically valid (e.g., that certain odors will reverse fatigue for any sustained period of time). Clearly, biobehavioral monitoring of fatigue is a promising area, but one that also needs to meet reasonable scientific and practical standards. A great deal of harm can be done if invalid and/or unreliable devices are quickly and uncritically implemented. This will result in wasted resources and provide only a false sense of security relative to performance-impairing fatigue.

Environmentally-centered technologies. There is also a range of environmental technologies associated with preventing fatigue-related performance deficits and catastrophe. These can include sleep environments in the

work place, which refers to the comfort, quiet, lighting, and related environmental facets of sleeping quarters in planes, trains, ships, and trucks. Such on-board sleeping environments are intended to promote recovery from fatigue. However, if the environment is not conducive to sleep (or is under-used), it may be of little value as a fatigue prevention system. There is a great deal of variability within and among transportation modes in on-board sleeping facilities, but little research on the topic. Laboratory data suggests that a comfortable (thermally, posturally), quiet, safe sleeping environment in which the sleeper can lie down is more likely to promote consolidated sleep and recovery than is one in which these factors are not present. More research of the kind that NASA has recently conducted on on-board crew rest facilities in longhaul aviation is needed to identify the most effective sleeping environments in the workplace (i.e., those that afford the best recovery from fatigue).

There is also emerging environmental technology associated with promoting alertness in the workplace. Bright light is an excellent example of such a technology--it has been much more extensively investigated than some of the other environmental countermeasures to fatigue. Some of the newer environmental technologies being developed include error detection systems and feedback technologies, and intelligent systems technologies (e.g., so-called intelligent highways). Shoulder rumble strips are also an example of an environmental technology intended to prevent catastrophic outcome.

One of the greatest concerns raised about environmental technologies, especially those that provide feedback on the operator's interaction with a system or the environment (e.g., shoulder rumble strips), is whether these technologies do nothing more than encourage people to be-

lieve that it is safe and acceptable to continue operating in a fatigued state. As an example of this concern, consider the problem of whether or not to install shoulder rumble strips along millions of miles of highway, especially sections with high run-off-road crash rates. The concern would be that shoulder rumble strips may not actually reduce crashes, but rather merely permit crashes to “migrate” from a highway area in which shoulder rumble strips have been added, to an area without rumble strips, further down the road. Presumably the environmental technology (in this case, shoulder rumble strips) prevented some crashes at one site by merely shifting them later in time, because many of the impaired drivers did not actually stop operating their vehicles upon encountering the technology. While there is very good evidence that shoulder rumble strips do reduce run-off-road crashes, migration has also been observed. Consequently, any environmental technology designed to promote alertness and prevent fatigue-related catastrophes must also be implemented in a manner that ensures it does not simply encourage even more unsafe practices. Therefore, as these technologies become implemented, research will be needed on exactly how people use them, and how effective they are at preventing fatigue-related outcomes. The same type of research will need to be performed on system-centered and operator-centered fatigue countermeasure technologies.

3. Challenges facing scheduling and the management of fatigue.

On the scheduling side, developments have been much slower. Scheduling is much more than “hours of service,” which form the backdrop or platform on which scheduling is supposed to occur across transportation modes.

Scheduling involves the thousands of different types of schedules that now exist in the world. A huge number of which are not circadian, meaning they do not even approximate a 24-hour work-rest period that would permit some adjustment by the circadian biological clock regulating alertness in humans. Two other critical challenges to scheduling technologies include the problem of work being done during non-work or rest hours, and work that is job related but that is classified as “voluntary” and, therefore, considered outside the scope of regulated hours. In terms of performance impairment, the brain does not care what caused the sleep loss or circadian loss of alertness leading to fatigue. The biology reacts the same way, regardless of whether someone remained awake for a prolonged period of time because he/she was working overtime, or was working a second job, or was caring for a sick relative. This means that everyone (worker, company, regulator, and public) share responsibility for ensuring that dangerous levels of fatigue on the job are not engendered either by poor work schedules, or by life style, or by voluntary work opportunities (excessive overtime).

The challenge of scheduling to manage fatigue is that with the full scale utilization of 24-hour operations in virtually all modes of transportation, has come a concomitant proliferation of work schedules (e.g., split shifts, flexitime, and compressed work weeks). Moreover, federal regulations governing hours of work in all major modes of transportation are dated, and uninformed by modern scientific data on the biological causes of fatigue and its effects on performance. In addition, these regulations are often out of line with actual industry practices. A significant issue that will continue to confront industries and governments involved in global economic competition is how to meet

the escalating demands to operate around-the-clock, often internationally and/or intercontinental, in a cost-effective manner, while ensuring that operators remain alert on the job. Interpretation of current U.S. federal statutes and regulations governing work-rest scheduling vary widely across transportation industries (e.g., the range in total hours of work allowed by law varies by more than a factor of two, mandated days off in a two-month period range from zero to 24, and attitudes about the need to enforce the regulations range from serious concern to casual disregard). In recent years there have been growing interest in the United States and Europe toward revision of the work-rest regulations to reflect industry/government economic needs, parity among labor constituencies, the public's perceptions of what they want to have regulated (this can vary markedly across industries), and the scientific data accumulated on the causes and consequences of performance-impairing fatigue. Whether this level of agreement is feasible is unknown, but to even approach it, constructive efforts from all parties will be essential.

While developments in scheduling technologies have lagged behind those for systems, operators, and the environment, there is currently at least one initiative underway to base changes in federal regulations dealing with limits on scheduled work hours in a transportation mode on scientifically derived principles and guidelines about fatigue/sleepiness (Dinges et al., in press).

4. The ultimate challenge is not a technological one.

Some technologies will eventually prevent or limit certain catastrophic outcomes due to fatigued performance. There is clearly great po-

tential for improving the safety margin with technologies and better scheduling. However, such developments should not be a substitute for setting standards for the functional capability of a transportation operator. This point is perhaps best made with an analogy to another risk factor. Imagine if a device was developed that could absolutely prevent 98 percent of all drunk driver crashes, and that it was to be installed in all modes of transportation. With this super device in place, would we, as a culture, accept the premise that henceforth it was acceptable for people to drive drunk? This is the ultimate issue we face in the fatigue area as well. Technologies may eventually prevent or limit certain catastrophic outcomes due to fatigued performance, but technologies are not substitutes for setting societal standards for the functional capability of an operator.

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Dr. Charles A. Czeisler

Harvard Medical School/Brigham and Women's Hospital Melatonin, Bright Light and Overnight Operations

November 1, 1995 -- Afternoon Session



Thank you very much, Dr. Rosekind. Chairman Jim Hall from the NTSB jokingly suggested that he had arranged for a melatonin pill to be on the cover of Newsweek today as a kickoff for this workshop.

It is a pleasure to have been asked by the NTSB and by NASA to make a presentation today. I am going to concentrate in this presentation on the countermeasures that can be used to try to correct some of the abnormalities associated with misaligned circadian phase, in particular on use of the hormone melatonin and on exposure to light.

The operational demands within the transportation industry, as has been already reviewed today, are quite disruptive to a number of the physiologic systems that control the timing of sleeping and waking and hence, affect alertness and performance. Transmeridian travel across multiple time zones, of course, causes a mismatch between the biological time of day, on the one hand, and the local time at which individuals are trying to operate on the other. This is often exacerbated by the extended work hours that are needed to travel due to the inherent nature of the transportation industry. Much transportation work is also done at night and requires a high degree of alertness on short

notice, often punctuating long intervals of relative boredom. Furthermore, we know from survey data that there is a high rate of near-miss and actual accidents in round the clock industries. In a survey of about 2,500 rotating shift workers, we found about 20 to 25 percent of rotating shift workers reported personal injuries and procedural errors, near misses, or even accidents, associated with sleepiness in the preceding year. Furthermore, about 28 percent of them report an actual or near-miss automobile accident due to sleepiness within the preceding year. Ninety-eight percent of those reported automobile accidents or near misses due to sleepiness occurred on a work day, with over 90 percent of those reportedly occurring while driving home from work after having worked the night shift. Indeed, the early morning hours represent a critical zone of vulnerability for individuals in the transportation industry. In fact, it was reported years ago that there is a 16 fold increase in the risk of a single vehicle truck accident due to sleepiness at that time as compared to the middle of the daytime (Figure 1).

So why is this particular time within the 24-hour day the most vulnerable? We have already heard from Dr. Dinges and Dr. Rosekind explanations of the physiologic bases of this vulnerability, and Dr. Dinges spoke extensively

about lapses of attention which occur under this circumstance. Figure 2 shows EEG recordings by Torsvall and Åkerstedt in Swedish train drivers on an overnight trip from Stockholm to Malmö in the south of Sweden. It is rare to have actual EEG recordings of individuals during the night shift, although Dr. Rosekind and Dr. Dinges have recorded similar tracings in airplane pilots. The upper panel of Figure 2 illustrates two tracings of the EEG from an alert driver. As you can see, the eye movement tracing indicates many eye blinks. The low voltage mixed frequency signal in the EEG tracing indicates an awake and alert individual. The lower four tracings illustrate data from a sleepy individual driving a train. The eye movement tracing from this sleepy driver indicates that his eyes are rolling around in their sockets. He also has episodes of synchronous activity in the EEG, as occurs during sleep. Midway through this record, the train driver passes right through a pre-stop signal and fails to apply the brakes until about 20 seconds later. Suddenly, the driver's heart rate jumps just at the point when he applies the brakes. This sluggish response illustrates the cognitive slowing that Dr. Dinges described in the sleepy individual. Actually, there was not another stop signal in the 20 second interval between the time the engineer first passed the signal and when he applied the brakes. Yet it took 20 seconds for the signal to pierce the consciousness of the train driver, and for him to realize that he had seen a stop signal some time ago but had not yet applied the brakes.

Why do such lapses tend to happen at night when we are at an adverse circadian phase? Because, as you remember from Dr. Dinges' lecture, one of the primary determinants of alertness and performance is circadian phase, which is determined by a light-sensitive pacemaker or clock located in the brain.

We can monitor individuals in the laboratory to find out what happens to their physiologic functions when they remain awake all night. The body temperature cycle reaches a nadir just before the regular wake time of the individual, and then the body temperature rises again. Subjective assessments of alertness drop to their lowest level at about the regular wake time. Those of you who have remained awake all night will often feel a surge of energy in the early morning hours just after dawn.

Many times, if exposed to the external light/dark cycle, people staying awake all night will think that it is the sunrise that has woken them up. Alternatively, one might guess that interaction with colleagues coming into work in the morning might provide this surge of alertness. But actually, even if we keep subjects in a lab where they are shielded from changes in the outside world, and we keep them in a constant posture with meals evenly distributed throughout day and night, a daily surge of alertness still occurs a few hours after their regular wake time. This surge is being driven by an internal biological clock. However, the peak drive for sleep is very close to the regular wake time of the individual, not at bedtime as you might imagine.

The release of the hormone cortisol continues its robust oscillation, even in this state of continued wakefulness. Daily variation of urine output, which is normally lowest at night when we are asleep and highest during the daytime when we are ordinarily awake persists even during a two day vigil of extended wakefulness.

Even the release of the hormone melatonin, which Dr. Richard Wurtman at MIT has called the hormone of darkness, continues to occur during the night. In nature, it is used to mea-

sure daylength, by sending a signal to the brain which allows seasonally reproductive animals to determine whether or not it is the appropriate season for breeding. In animals that do not normally reproduce during the winter, high levels of melatonin occur when the days are short and the nights are long, inducing testicular regression with a 90% loss of testicular weight, so that the animals are unable to breed during the winter. This was not mentioned in the Newsweek cover story on melatonin, although it was reported that decreased sex drive was one of the side effects recorded by some of the individuals taking melatonin. In the spring, when the days are long and the nights are short, there is less melatonin released because melatonin is inhibited by exposure to light. Inhibition of melatonin secretion is then associated with a recrudescence of the testes, followed by reinitiation of reproduction in those animals.

Cognitive performance, as measured by the speed of completing simple addition tasks, reaches a nadir just after the habitual waketime, in parallel with short term memory performance. In the short term memory task, the subjects are read a passage and then tested for simple recall of that information, without any cognitive reasoning required. At the nadir of the temperature cycle, near the habitual wake time, performance on that task is significantly degraded as compared to the daytime.

Now, what can we do about a biologic system in which the brain is gearing down to be asleep during the night time hours, even if that is the time an individual needs to be active and awake in order to fly an airplane or drive a train? Well, planned exposure to light can actually reset this internal biological clock, shifting it so that we are alert and awake at night and asleep during the daytime. The brain contains the internal biological clock or circadian pacemaker in the

suprachiasmatic nucleus of the hypothalamus, or SCN for short. There is a direct connection between the retina in the eye and this pacemaker or clock in the brain. Animal studies have demonstrated that even after transection of the pathways necessary to mediate conscious vision in the brain, resulting in behavioral blindness, the internal clock of those animals can still be reset with exposure to light. It is not necessary to be consciously aware of the light in order for it to reset our internal clock. We have since confirmed those observations in a subset of blind humans.

One of the things that we have shown is that if we determine what time of day it is in an individual's body by charting a physiologic function, and we expose that individual to several consecutive days of bright light at night and darkness during the day, then within a few days the pacemaker can be reset. Such light exposure can reset the pacemaker by up to 12 hours within 2-3 days.

On the other hand, if we are exposed to darkness during our new daytime, our internal biological clock will not adapt to a change in time zones, even though we have shifted the timing of when we sleep and wake, along with our entire meal schedule, our social interaction schedule, and all the other things that go along with changing time zones.

It is not just the timing of the body temperature cycle that will shift in response to light exposure, but also the timing of the release of the nocturnal hormone melatonin. If we expose an individual to bright light, we can shift the body temperature cycle so that the nadir occurs at an earlier hour, and we can also then shift the release of the hormone melatonin so that instead of being released during the hours from 10:00p.m. to 8:00a.m. it is released in the

afternoon and evening hours. The resetting response of this biological system to light depends on the time at which the light stimulus is given. Just as Dr. Roth was indicating a moment ago with regard to pharmacologic agents, you need to plan both the timing of the light exposure as well as the dose to induce a desired response.

In response to the timing issue, if you give the light exposure in the middle of the day it will have little resetting effect. For example, if you were to go outside and be exposed to very bright light at 4:00p.m., that would minimally reset your internal biological clock. Whereas if you were to be exposed to that same light stimulus in the middle of your biological night at 4:00a.m., such as might occur if you were piloting an aircraft from Washington, D.C. to Tokyo, then several consecutive days of bright light exposure could reset your biological clock by up to 12 hours, depending on the exact timing of the light exposure.

We have done some studies in the laboratory to determine the potential use of this approach among shift workers who are regularly working at night. Subjects from our control studies began their first night shift when their body temperature cycle was reaching its nadir during the shift. As a result, they were very sleepy during the scheduled work time on this first night. After they worked for a week in standard room light, then at the end of that week, on the sixth night shift, they were still reaching the nadir of their body temperature cycle at that adverse phase, because the internal biological clock was not adjusted to a night work schedule. In fact, people can work at night for years and fail to adjust to their night work schedule. Exposure to bright light in the outdoor world on the way home from work sends a signal to the brain indicating that it is day-

time. That daytime light exposure overpowers the impact of the much dimmer artificial light to which they are exposed while working at night, and keeps them on a schedule in which they are fighting the brain in order to stay awake at night and then fighting the brain to try to sleep during the daytime.

On the other hand, if you enhance the exposure to bright light during the night shift, and protect the day time sleep so that it occurs in darkness, then you can essentially trick the brain so that it adjusts to night work. People can then be at their peak during night work, and at their nadir during the subsequent day sleep. In our study, none of the subjects in the control group adapted to the night shift schedule, whereas all the subjects in the treatment group successfully adjusted to their schedule of night work and day sleep. If we examine their body temperature, alertness, cognitive performance, kidney and hormone activity, it is evident that the group that received the treatment were at their peak of alertness during the night shift instead of at their nadir, and they were at their low point of alertness during they day sleep, which is appropriate. In contrast, those in the control group did not adjust physiologically to working at night, and continued to reach their temperature, alertness and performance nadir during the night shift hours, even after a full week on the schedule.

The subjects in the control group slept an average of 5.7 hours per day, so that over the course of a week they lost a full night of sleep. In other words, they lost at least eight hours of sleep over the course of a week of night shift. As Drs. Dinges and Rosekind pointed out, such chronic partial sleep deprivation leads to deterioration of alertness and performance and increased risk of error or lapsing of attention. In contrast, the individuals in the treated group,

who were exposed to enhanced lighting in the work place, slept an average of two hours more per day and avoided the potentially dangerous loss of a full night of sleep during the week of night work.

Our first application of the use of bright light to the workplace was in the transportation industry, albeit in an unusual mode of the transportation industry, among the crew of NASA's space shuttle Columbia. The shuttle was scheduled to launch at night and the crew therefore had to invert their sleep-wake schedules by 12 hours in order to be prepared for night activity and day sleep. The crew were then expected to remain on that schedule throughout the ten or 14 days of the mission, with some minor variations. The particular crew of the first shuttle (STS35) with whom we worked in 1990 were on that inverted schedule for weeks prior to the mission, since that was the mission that was delayed because of hydrogen leaks for many weeks. Throughout that time, the crew kept trying to stay awake at night and sleep during the day time. We installed enhanced lighting in the pre-launch quarantine area for the crew members. The commander of that mission reported that on the first night of augmented light, the crew accomplished more than in the previous several weeks, when they were trying to stay awake at night in ordinary room light. We put them on a schedule in which they were exposed to enhanced light intensities during their anticipated day, and darkness during their anticipated night sleep. By the time they were ready to launch, the timing of the release of melatonin was inverted, such that it was being released during their day time sleep instead of during their waking night.

There has been speculation and some scientific evidence that direct melatonin administration could be used to reset the internal bio-

logical clock in humans. It has been reported that daily melatonin administration for four consecutive days can reset the melatonin rhythm by up to an hour or two. However, in those studies, subjects were living in the outdoor world and their exposure to natural outdoor light was not controlled. Since light can reset the biological clock by up to 12 hours within a few days, it is not known without controlling for light whether or not melatonin is really in and of itself effective as a phase resetting agent in humans.

In fact, in blind individuals, the results from clinical studies indicate that although it appears to aid sleep in some blind individuals, it does not appear to be able to entrain or reset the rhythmic markers that we use to track the output of this internal biological clock in the absence of light input to the pacemaker. So, in my view, notwithstanding today's cover story in Newsweek, it is not clear whether or not melatonin is effective at resetting the human biological clock.

Apart from circadian phase, one of the main determinants of alertness and performance is the amount of time that we are awake during the waking day. To study the interaction between the time of day and the lengths of time awake, Dr. Derk-Jan Dijk and I have used a protocol that was developed by Professor Nathaniel Kleitman more than 50 years ago, when he spent a month in Mammoth Cave in Kentucky. When he went into Mammoth Cave, Dr. Kleitman put himself on a schedule that transmeridian travelers would find to be quite a nightmare. He put himself on a schedule in which every day he crossed anywhere from three to four time zones, and he did that for a week. In one case he lived on a 28 hour day, going to sleep four hours later each day, as if he were travelling westward by four hours. In

one week, even though he only had six sleep episodes on this 28 hour schedule, he still had seven cycles of his body temperature. In another experiment, he put himself on a schedule where every day he went to bed three hours earlier, the equivalent of flying eastward three times zones each day. Although he had eight 21 hour days during a week on that schedule, he still had seven cycles of his body temperature. We have taken that paradigm and extended it for a month. Under these circumstances in the lab, the internal biological clock begins to oscillate at its own intrinsic period, which as Dr. Rosekind mentioned is a little longer than 24 hours. Dr. Theresa Shanahan has shown that the timing of the release of the hormone melatonin and the timing of the body temperature cycle continue to oscillate with a near-24-hour period, in synchrony with each other. This protocol allows us to study what happens to individuals sleeping and waking at all different phases of an internal biological clock. By looking across days on that 28-hour schedule, we find that even within the normal waking day, there is a substantial decline in alertness and performance that occurs within the first 16 to 18 hours of our regular waking day. Our alertness and performance are actually declining between 8:00 a.m. and 10:00 p.m., due to the length of time that we have been awake. We do not usually notice that because our internal clock is timed to peak in the latter half of our waking day. As our alertness declines because we have been awake longer, and as our performance would otherwise be deteriorating, our internal clock is actually improving our alertness throughout the waking day. Thus, the internal clock promotes alertness as the day goes on, opposing the decline of alertness which would occur if we remain continuously awake. Those two forces normally interact to allow us to maintain a stable level of alertness throughout the day.

But if you schedule an individual to begin driving at 10:00p.m. and continue driving all night, this precisely timed system is turned upside down. So instead of working in concert, interacting to maintain a high level of alertness, circadian and homeostatic factors make alertness in the latter half of the night worse, and worse, and worse. That is probably why there is that 16 fold increase in the risk of single vehicle truck accidents in the hours from 3:00 to 6:00 in the morning (Figure 1). To make matters worse for the night driver, it is then difficult to sleep during the day time, because these same two systems control the ability to sleep.

One is the homeostatic drive for sleep, which depends on how long you have been awake. While you will have plenty of homeostatic sleep drive if you have been awake all night, the circadian clock is actually poised to make it difficult for you to sleep during the day time.

When individuals try to sleep at an adverse circadian phase, particularly in the afternoon and evening hours, there is a great deal of waking that intrudes upon their scheduled sleep episode. We estimate that on average, 25-50 percent of the time they will be awake if they try to sleep at an adverse circadian phase, depending on their age. This is very discouraging to people. They lie down and while they may fall asleep, they can't stay asleep (Figure 3).

This is where the hormone melatonin may help some day. Rather than shifting the biological clock, some data indicates it may help to promote sleep at adverse times when melatonin is not naturally being released. If you give the hormone melatonin during the day time, a 1994 study reported that it can help to promote sleep during a 10-minute nap.

That 10 minute nap experiment has driven the most intensive public relations promotion of melatonin that I have ever witnessed for any compound. Newsweek said something pretty striking in the article on melatonin in today's issue. They reported that in early August, something happened to cause a dramatic increase in the sale of melatonin. Perhaps it was related to the fact that the day after their August article on melatonin appeared, sales rose more than ten fold in health food shops across the nation. Now Newsweek has a second article reporting on this melatonin craze, on the front cover of the magazine. Well it seems to me that if Newsweek looked inward they would realize that they are driving this "melatonin craze" with all of this publicity. No other hypnotic has been allowed on the market with so little clinical trial data collected. In my opinion, it is really much too early to promote melatonin as a sleep promoting hormone. If after controlled trials, it does turn out to be effective, it could be used to help promote sleep during the time of day that we do not ordinarily sleep and that we do not ordinarily produce this hormone.

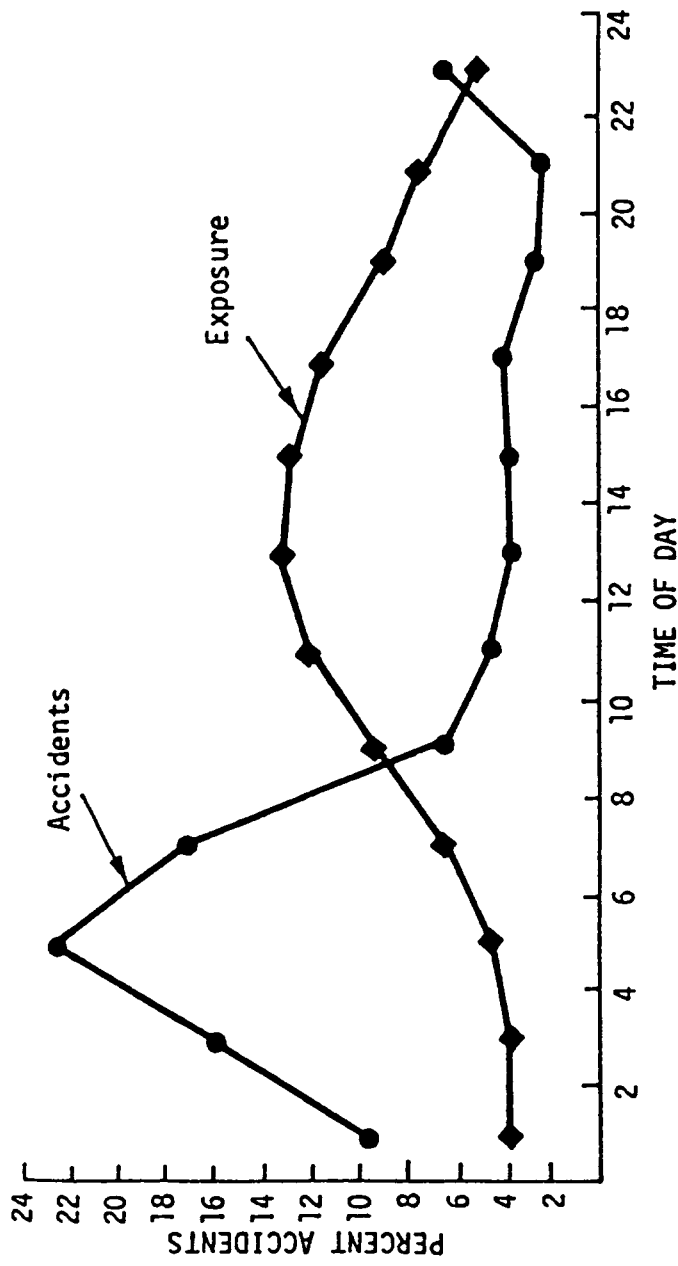
Finally, I believe that the transportation industry desperately needs an educational campaign on sleep and circadian rhythms. Such an educational campaign could prevent the kind of situation that I found prevailing in Albany a few years ago. I spent three years flying from Boston back and forth to Albany testifying because the chief of the fire department there wanted to set a limit on shift duration for the paramedics driving the ambulances in Albany. He wanted to limit them to no more than 24 hours of service. But since the employees were paid premium overtime for each additional 24 hours that they worked, they were suing the City of Albany, arguing that they should be allowed to work longer by a contract that was

established 40 years ago, which allowed up to 72 consecutive hours of service.

The remarkable thing to me, after three years of testimony, was that in the end the City of Albany had to pay all the back wages to all those individuals who were not allowed to work up to 72 hours in a row, and the fire chief was forced to change his scheduling practice so that individuals were again scheduled for service as paramedics working up to 72 hours in a row. I find it remarkable that in a civilized society - given what we know about the dangers of sleep deprivation -- such a practice is allowed and even mandated by the legal system to continue. I do not think anyone who has a heart attack would want to have an IV line placed by someone in the field in their 70th hour of work, or to be driven from the scene of the incident or accident across our Nation's highways to the hospital by a paramedic who has been on duty for 70 hours. Yet we have no policies in this country which prevent that kind of abuse from happening. I believe that an effective educational campaign could improve such situations. We also need Federal guidelines limiting the number of consecutive hours of service allowed in all industries in which performance degradation can cause accidents. People in such jobs should not be allowed to work such inhuman hours. Unfortunately, the risks they now choose to take are not just their own lives.

Thank you very much.



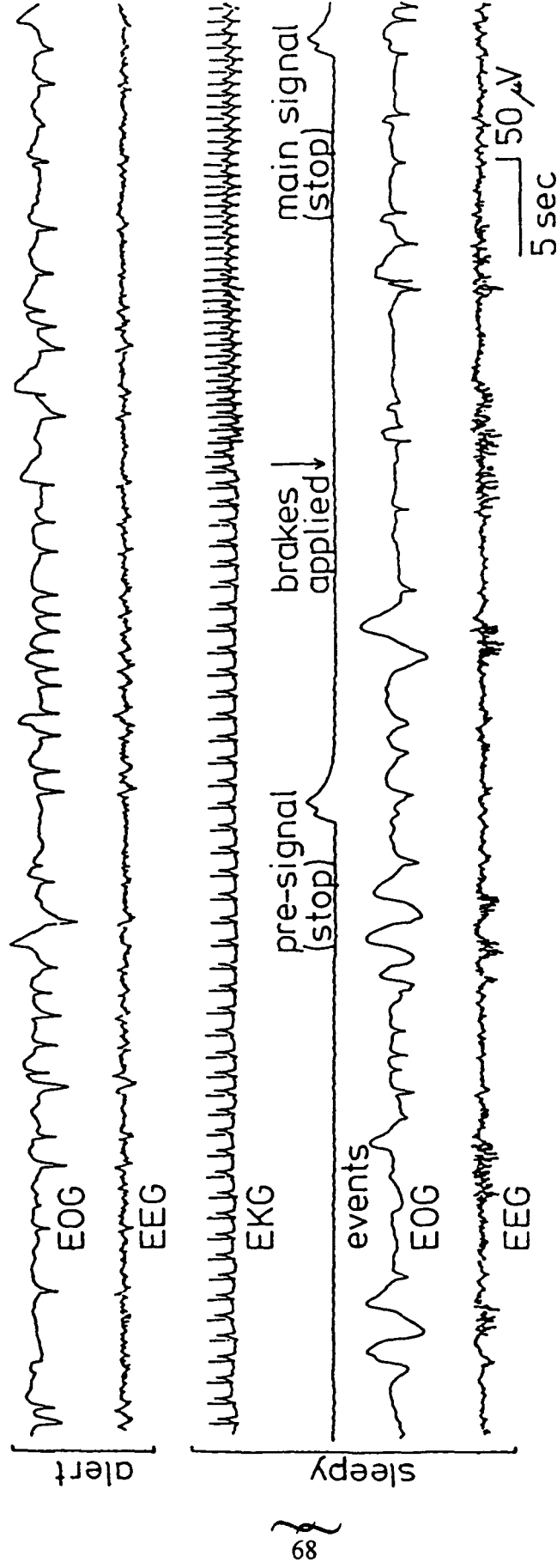


Percentage of accidents by time of day for dozing drivers and normalized percentage of trucks on the highway for a random sample of interstate drivers (exposure).

Reproduced from: W. Harris "Fatigue, Circadian Rhythm, and Truck Accidents" in *Vigilance: Theory, Operational Performance, and Physiological Correlates* edited by R. Mackie, New York: Plenum Press, 1977.

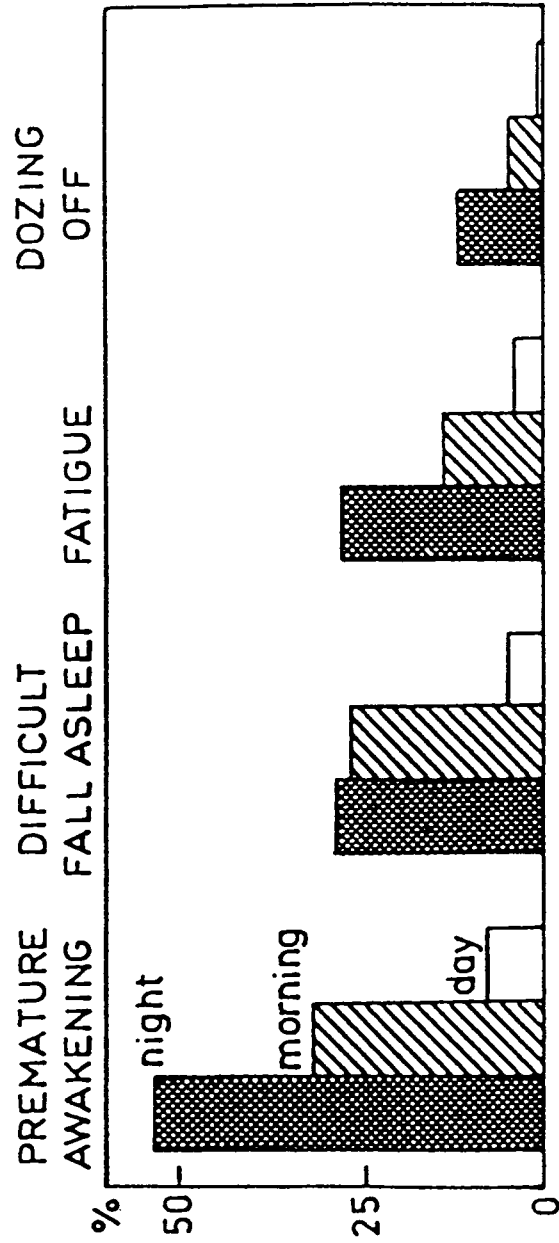
Figure 1

Figure 2



Above: detail of the EEG and EOG (ECG added) record during an alert part of the night journey. Below: detail of the record around the first performance lapse.

Reproduced from: Torsvall et al. "Sleepiness on the job: continuously measured EEG changes in train drivers" *Electroencephalography and clinical Neurophysiology*, 66:502-511;1987.



Percentage of a sample of 1000 train engineers reporting four sleep/wake problems to occur “sometimes” or “most of the time” in connection with night, morning, and day work.

Figure 3

Reproduced from: Åkerstedt et al. “Sleepiness and Shift Work: Field Studies” Sleep, 5:S95-S106;1982.

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November 1, 1995



Sleep disorders are common in America society.¹ There are a large number of sleep disorders² but there is more information about some. Thus, in this presentation I will limit myself to discussion of three sleep disorders—chronic insomnia, narcolepsy, and sleep apnea. There are studies on the impact of these conditions on transportation. But this literature is almost exclusively related to transportation by car. There are some studies related to commercial surface vehicles, i.e., trucks, but not to my knowledge to other modes of transportation.

Insomnia and Transportation

Insomnia is a condition in which there is difficulty initiating or maintaining sleep. Individuals with this disorder will complain of the following: difficulty in getting to sleep; waking up in the middle of the sleep period and being unable to reinitiate sleep; waking up too early. Many individuals with this problem will have more than one such complaint. Insomnia can be transient, e.g., associated with bereavement of a close relative or other stressful situation, or it can be long-lasting. Chronic insomnia is considered to be a condition in which the insomnia lasts for more than three weeks.³ Survey studies show chronic insomnia affects 9-10% of the American population.^{4,5} A recent

Gallup survey conducted on behalf of the National Sleep Foundation found that 12% of Americans had frequent, chronic difficulty sleeping.⁶ Difficulty sleeping can impact daytime performance. A 1991 Gallup survey found that individuals with chronic insomnia reported twice the crash rates of individuals without this problem.⁷

Narcolepsy and Transportation

Narcolepsy is another sleep disorder which is associated with an increased crash risk. It is a much less common condition and it is estimated that it affects 250,000 Americans.⁸ It is a disorder that usually begins in adolescence.⁹ There are four main clinical features but not all individuals with this disorder will have of necessity all of the features.⁹ The features are: a) excessive daytime sleepiness. Individuals with this disorder can be very sleepy during the day; b) cataplexy. Here individuals with narcolepsy can have sudden loss of muscle tone precipitated by emotional events. Loss of muscle tone normally occurs as part of rapid eye movement (REM) sleep (dream sleep). Thus, in narcolepsy this aspect of REM sleep can be triggered by emotion. The most common emotion that triggers cataplexy is laughter, although other emotions can also do so.⁹ Severe cataplectic attacks can result in individu-

als falling to the ground; c) hypnagogic hallucinations. This feature is related to the abnormalities in REM sleep in patients with narcolepsy. They may experience vivid dreams at sleep onset when they seem still to be awake; d) sleep paralysis, which is the experience of being unable to move when one wakes up. This occurs intermittently in about 10-12% of the normal population. It is, however, a more common phenomenon in individuals with narcolepsy. Sleep paralysis is likely to be caused by the loss of muscle tone that is found in REM sleep being continued for a period after the individual wakes up.

Narcolepsy is a chronic condition. It lasts throughout the individual's life. It does not usually get progressively worse but rather there is a variation in the intensity of symptoms. The basis for this variation is unknown. The disorder can be managed by medications to combat the sleepiness. Such medications are stimulants that include amphetamines. There is a new medication—modafinil—that is currently used in Europe. It is awaiting approval by the Food and Drug Administration (FDA). It is a medication that acts in a different fashion than amphetamines and has no abuse potential. Naps can also be extremely useful in narcolepsy since they ameliorate the sleepiness.

Narcolepsy is, not surprisingly, associated with an increased risk of vehicular crashes when untreated.¹⁰ There are, however, no data about whether individuals once treated with narcolepsy have an increased crash risk. This is an essential piece of information to guide appropriate public policy. Currently there are limitations of driving privileges of individuals with narcolepsy in certain states and some countries.¹¹ The regulations vary, however. In general, for the non-commercial driver the regulations propose denying driving privileges

on diagnosis with the driving license being restored when the condition is controlled for a period, e.g., 3-12 months. In certain localities, e.g., Texas, United Kingdom, Canada, Australia, individuals with narcolepsy can never be drivers of commercial vehicles.¹¹ There are to my knowledge, however, no studies of crash rates of commercial drivers with narcolepsy. This is not surprising and there are not likely to be. Narcolepsy is a relatively uncommon condition and it would seem likely that individuals with this disorder would not seek employment as commercial drivers.

Sleep Apnea and Transportation

Sleep apnea, on the other hand, is a much more common disorder. There are considerably more data about this disorder. In this condition the upper part of the airway narrows and may even completely close (apnea) during sleep. As a result oxygen levels in the blood decline, a change which is sensed by the brain. The brain produces an arousal, i.e., a brief awakening from sleep, during which the muscles of the throat open the upper airway. As a result sleep in this condition is considerably fragmented and is not as restorative as normal sleep. Hence individuals with this disorder are excessively sleepy during the day.

The condition is extremely common. If one uses criteria to make the diagnosis based on presence of daytime sleepiness, night-time symptoms and breathing abnormalities during a night-time sleep study, it affects 4% of middle-aged men and 2% of middle-aged women.¹² If the diagnosis is only based on the results of the sleep study alone then these numbers rise to 9% of middle-aged men and 4% of middle-aged women.¹² There is, however, a continuum of abnormality. There are many

individuals with mild disease but fewer with the most severe forms of the disorder. It is important to keep this in mind when designing public policy. Mandating testing would identify many individuals with milder forms of disease in whom the significance for the transportation industry is currently not known.

Since sleep apnea interrupts sleep and causes individuals to be excessively sleepy, it is not surprising that sleep apnea is associated with reduced driving skills and an increased risk of vehicular crashes.

Sleep apnea results in impaired driving performance. This has been shown in studies in driving simulators¹³ and in the divided attention task that has been extensively used to study driving impairment produced by alcohol.¹⁴ Patients with sleep apnea may perform as poorly as individuals who are above the legally acceptable blood alcohol concentration.¹⁴ Patients with sleep apnea also have an increased crash rate,¹⁵ although the studies showing this were based on a small sample of individuals. Retrospective analysis showed that patients with sleep apnea have approximately a three times increase in crash rate in the previous five years as compared to all other drivers in the state of Virginia, where the study was done.¹⁵ There is some suggestion that sleep apnea is more common in commercial drivers.¹⁶ This is likely because obesity is more common in this group;¹⁷ obesity is the major risk factor for sleep apnea.¹² Commercial drivers with sleep apnea had twice the crash rate in a recent study,¹⁶ a result widely reported in the press in the United States. But this statement is misleading since there was no significant difference in crash rates in commercial drivers with sleep apnea as compared to those without apnea.¹⁶ Thus, currently there are no definitive data that commercial drivers with sleep apnea

have an increased crash risk. It would seem likely that this is the case but studies are required to examine this question.

There are treatments available for this disorder (for review see 18). The most commonly used treatment is nasal continuous positive airway pressure (CPAP). During sleep the individual wears an attachment, e.g., mask, that connects their nose to a small machine that delivers pressurized air through the nose to the back of the throat. This pressurized air acts to push open the walls of the upper airway thereby preventing snoring and upper airway collapse. It is an extremely effective treatment. There are, however, problems with patient compliance. About 40-50% of subjects starting this therapy use it very intermittently.¹⁸ There are some data that when CPAP is used as a treatment for sleep apnea, crash rates are reduced.^{19,20} Other treatments that are included are an intra-oral device which is worn during sleep.²¹ This device pulls the jaw forward and enlarges the upper airway thereby making collapse and snoring less likely.¹⁸ Surgical treatments are also available (for review see 18).

What Needs to be Done?

The issue about sleep disorders and transportation is complex. The biggest single issue is related to sleep apnea both because it is so common and it is the disorder about which we have the most data. There are already strongly held opinions, albeit not based on scientific study, about the steps we need to take. This author is in favor of an incremental approach to the problem based on sound scientific investigation. As we move forward we need to address the following questions: a) should sleep apnea be screened for as a condition of employment in transportation?; b) if so, how do we do so cost-

effectively? Routine expensive laboratory sleep studies at a cost of around \$1,000 per study, which is advocated by some, is not, in my view, a viable public policy; c) if sleep apnea is diagnosed in, for example, a commercial driver and that individual cannot continue employment, should he/she be given disability payments? Again we could be facing staggering economic costs if we moved in this direction; d) what is the responsibility of the employer and the employee in the event that a major accident is attributed to untreated sleep apnea? Each of these are difficult issues will, over the next several years, presumably be the subject of much public and scientific debate.

For the present, the first step that we need to take is, in my view, increased awareness of the issue. We need to put programs in place to inform employers, employees, families of employees, and safety officials about sleep apnea and in particular, how to recognize it and treat it. We particularly need to carry out aggressive education of physicians who are responsible for pre-employment physical examinations of employees and for their annual physicals. Since sleep disorders is a relatively new field of medicine with little formal teaching in medical schools,²² there is limited knowledge or expertise about sleep apnea among practicing general physicians.²³ A sustained educational effort should lead to increased case recognition and treatment of individuals with this disorder. Methods to track case recognition following implementation of such educational programs should be put in place. Employers can reasonably assume that somewhere between 4 and 9% of their work force will have this disorder.

To compliment this educational effort, forms etc. that are used for medical evaluation should include questions that elicit symptoms of sleep

apnea, i.e., loud, frequent snoring; witnessed apneas; snorting and gasping during sleep, as well as complaints related to excessive sleepiness. Obesity is a major risk factor for sleep apnea, in particular fat in the neck area. Thus, neck (collar) size should be documented since this is the best physical measure to help determine whether sleep apnea is present. We know that the prevalence of sleep apnea in individuals who snore and have a collar size above 17 inches is around 30% (T. Young, personal communication).

As these educational activities are being put in place, we need to do research to establish and evaluate cost-effective ways to screen for sleep apnea. Such approaches could include a two-stage process involving first filling out a questionnaire and then having a simple test performed at home. The most likely test to be used for screening is measurement of overnight oxygen levels using a simple device attached to the finger, i.e., oximeter. There is some evidence of its efficacy as a screening tool²⁴ and a single test is likely to cost of the order of \$50. Research needs to be done of the efficacy of this approach in transportation companies. It is to be realized, however, that this concept of screening for sleep apnea will likely lead to a number of new medical companies proposing that they can fill this need. Employers should be concerned about the quality of these efforts and whether the approach being advocated has been validated in rigorous studies.

As these technological developments are taking place, there will also be a need to develop fora to discuss the difficult issues that these disorders raise. Legal experts and experts in public policy need to be attracted to the issue so that the debate is fully informed with all different perspectives being involved.

In conclusion, sleep disorders likely represent a common but treatable, and hence preventable, cause of operator impairment. They, therefore, represent an opportunity for the transportation industry to improve performance. It is an opportunity that the various components of this industry should work together to take advantage of.

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MANAGING FATIGUE IN TRANSPORTATION: Promoting Safety and Productivity

Keynote Address by
Dr. William Dement
Stanford University
November 1, 1995



Because these Proceedings may be read by policy makers and others who have not been exposed to sleep knowledge, I thought a “side bar” which introduces or re-introduces a few basic definitions and conclusions would be helpful.

What is Sleep? There are many sleep behaviors which can be simulated in the waking state - immobility, eye closure, snoring, to name a few. We should ask then, what is the fundamental difference between a human being awake and a human being asleep? Answer-- The crucial event that occurs as we fall asleep is an actively initiated shut down of our ability to see and hear the world around us. At one moment we are awake and can see, and a fraction of a second later, we are asleep and completely blind. Another way of saying this is that sleep is a behavioral state of complete perceptual disengagement from the environment.

Another fundamental fact is that sleep consists of two entirely different organismic states which are called REM sleep and non-REM sleep. These two states contrast markedly and alternate with one another in a basic sleep cycle throughout the night. The two chief characteristics of REM sleep, in addition to the oc-

currence of rapid eye movements, are (1) its association with dreaming and (2) its association with flaccid muscular paralysis, an inability to move any of the voluntary muscles except the diaphragm. When an entire night of sleep is considered, we typically see an orderly sequence of sleep stages defined by brain wave patterns with deep sleep occurring early and giving way to light sleep and longer REM periods later.

How much sleep do we need? Each of us, needs a certain amount of sleep each day on the average. If this amount is not obtained, a **sleep debt** is created. In other words, if the needed amount is not obtained habitually, the lost sleep accumulates progressively as a larger and larger sleep indebtedness. The average adult sleep requirement is a little over eight hours, and the great majority of individuals would fall within a range of plus or minus one hour. A powerful mechanism in the brain regulates the daily amount of sleep by progressively increasing the tendency to feel drowsy and to fall asleep in direct proportion to the size of the sleep debt. This process ensures that most people will average the amount of sleep they need, or close to it, over time.

What causes us to get sleepy? Prior sleep loss determines the strength of the tendency or ability to fall asleep. If your sleep debt is zero, sleep is impossible. If the sleep debt is very low, a very small amount of stimulation can keep us awake. If the sleep debt is very large, no amount of stimulation can keep us awake. It should be clear that all of the things we say cause us to become drowsy or to fall asleep actually are not causal. A reduction of stimulation only unmasks the tendency to fall asleep that is already present. To say that boredom causes sleep is wrong. If boredom is quickly followed by drowsiness, we are carrying a large sleep debt and we need stimulation to avoid falling asleep.

America is a sleepy society. How many Americans are seriously or dangerously sleep deprived? There is no doubt whatsoever that vast numbers of us in school, in the workplace, in the transportation industry, in a variety of service industries, and particularly, in shift work situations, are carrying a dangerously large sleep debt.

In one of the best scientific studies, investigators studied several hundred people who said they had no problem with daytime drowsiness. Using a precise measurement of sleep tendency, they found that 25% of the test population was dangerously sleepy. We have studied smaller samples at Stanford, for example, students and nurses, and have found that the percentage who are dangerously sleepy can be as high as 80%. By dangerously sleep deprived, we mean, of course, a dangerously high risk for some sort of accident involving inattention or unintended sleep. In all walks of life, it is likely that sleep deprivation has consequences: diminished productivity, mistakes, irritability, fatigue. For most people, the accumulation of a serious sleep debt appears to

have been so gradual that they attribute negative consequences to many other things and so do their doctors.

What is the Biological Clock ? What does it do for us? The biological clock is a term applied to the brain process which drives our daily rhythms in body temperature, hormone secretion, and a host of other bodily activities. Its most important function is to foster the orderly alteration of sleep and wakefulness. An important scientific breakthrough was the discovery of the precise location of the biological clock. It is housed in two tiny bilateral areas of the brain called the suprachiasmatic nuclei. Its major role in terms of sleep and wakefulness is to provide an internal and very powerful wake-up signal to the rest of the brain. This is the clock-dependent alerting that powerfully opposes the tendency to fall asleep and in the absence of other stimulation is sufficient to keep us awake all day if our sleep debt is relatively low. In the ordinary 24-hour environment, clock-dependent alerting is generally synchronized with the daytime, but if we travel rapidly to other time zones, it is not, and we experience "jet lag."

What are sleep disorders? Sleep disorders are illnesses and disturbances of sleep and wakefulness that are caused by abnormalities existing only during sleep, or abnormalities of specific sleep mechanisms. These abnormalities frequently produce symptoms that are recognizable during wakefulness, but the fundamental pathology exists during sleep. Though the symptoms that exist during wakefulness can be helpful in recognizing the possible existence of a sleep disorder, an absolute certainty requires an examination of the patient during sleep, widely known as a sleep test, or polysomnography.

Which sleep disorders are commonly associated with excessive sleepiness? Any sleep disorder which is associated with a reduction or fragmentation of sleep has the potential to cause the victim to be excessively sleepy in the daytime, or if a shiftworker, whenever the major wake period occurs. The disorders which are most typically associated with severe fatigue while awake are obstructive sleep apnea and narcolepsy. Others include the chronic insomnias, Restless Legs Syndrome, periodic leg movement, and biological rhythm disorders.

How common are these sleep disorders? Very much more common than anyone knows is the best answer to this question. The national prevalence has been established for one specific disorder, *obstructive sleep apnea*, at 24% of adult males and 9% of adult females. Separate studies in elderly populations and non-adults allow us to conclude that 30 million Americans are victims of this sleep disorder across the full range of severity.

What is obstructive sleep apnea? Sleep apnea is a disorder whose victims cannot breathe when they fall asleep. The word *apnea*, refers to the absence of breathing. The failure to breathe is caused by the collapse of the tissues of the throat producing closure of the airway. Once this has occurred, the victim may continue to make respiratory efforts without air-flow. Blood oxygen drops and finally triggers an alarm response so that the victim wakes up to breathe. In a severe condition, this occurs hundreds of times as the sleep deprived victim immediately returns to sleep. In the morning, these hundreds of awakenings are completely forgotten. If the sleep apnea condition has progressed to a level of severity, it is almost always associated with cardiovascular disease. Victims have high blood pressure, which is dif-

ficult to control, and are likely to have already had heart attacks or strokes. It also causes severe cardiac arrhythmias during sleep and these arrhythmias can be fatal. In addition, severe obstructive sleep apnea causes overwhelming daytime fatigue. This occurs because the victims must wake up hundreds of times to breathe and therefore sleep loses its restorative power. The condition is frequently misdiagnosed as chronic fatigue syndrome, or hyperthyroidism, or depression. The cardinal symptom of the disorder is loud snoring.

Drowsiness is a Red Alert! Vast numbers of us are suffering from a sleep disorder or sleep deprivation or both. The final, common path of impairment and danger is sleepiness. In the sedentary highway, rail, air situations, we progress toward serious impairment. Our eyelids get heavy, our heads sag, we feel that wave of strong drowsiness. All hard driving, sleep deprived readers should take this admonition very seriously. **Drowsiness is red alert!** Drowsiness is the last step before sleep, not the first. Drowsiness means you are at the abyss. I believe that if we all would respond to the first wave of drowsiness as an alarm-- as an emergency requiring an instantaneous response-- huge numbers of human tragedies, suffering, and catastrophic events would be avoided.

And lastly - The area of fatigue and transportation cries out for additional research to assess the precise magnitude of the problem and to perfect effective countermeasures. In addition, there must be a cultural change in which corporate, federal, and regulatory leadership make fatigue a major priority and hold individuals and institutions accountable.

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After editing the transcript of my remarks for these "Proceedings," I was a little uneasy that they did not get right to the point with regard to a number of key issues. Anyone who is not interested in "historical background" and after dinner anecdotes should skip the next few pages.

Thank you all very much. As the "After Dinner Speaker," I at least have the advantage of being able to comment on some of the events of the day. First on my list is to acknowledge the stunning success of this meeting. I believe that nearly 600 of the 1000 individuals and organizations invited are here from all over the United States. This is surely some kind of record, but more important, it validates the theme of the meeting, its importance, and its timeliness. All of the organizers deserve high praise. Of the many, I will single out Mark Rosekind and Julie Beal for their key roles. I also want to acknowledge the leadership and vision of Chairman Jim Hall. His remarks this morning were truly inspiring. Speaking as one of the so-called "pioneers" of sleep research, it is a thrill to be here, and the purpose is surely a meaningful culmination and validation for the many laboratory and operational investigators who have worked so hard on the problem of fatigue and transportation safety. Finally, I wonder if Board member Hammerschmidt knows that there is an Arkansas Sleep Society. I can assure him of its existence. I was at the founding meeting.

This is a very appropriate occasion to announce a recent landmark event. In the Senate Transportation Appropriations Bill, there was a line item, a small incremental appropriation for the National Highway Traffic Safety Administration to support a "driver fatigue initiative." The House version of the Transportation Appropriations Bill did not include this item. However,

with the support of Representative Frank Wolf, Chairman of the House Appropriations Transportation Subcommittee, the Conference Report which just came out included this funding in the full amount. The initiative is highly specific in addressing fatigue and its consequences on our highways, and it is intended to be continued in subsequent years. You all applauded one of our Congressional guests, Stephanie Gupta, earlier in the day. She certainly deserved the applause because she is the accountable staff member. We must also recognize the leadership of Senator Mark Hatfield and his staff who thoroughly understand the problem of fatigue and its consequences, and who originally introduced the legislation.

I think part of the reason this meeting is so successful, and part of what brought you all here, aside from, of course, the imprimature, the prestige and scientific integrity of the National Transportation Safety Board and the National Aeronautics and Space Administration, is the clear understanding that our purpose is to tackle the problem of fatigue. We are no longer debating if it is a serious problem. That is behind us. We are here to do something about it.

I might just say a few words about how I got started in sleep research. Earlier in the day, one of the speakers, Dr. Charles Czeisler, mentioned Professor Nathaniel Kleitman. At the time, I wondered how many of you had heard of Professor Kleitman, and were aware of his accomplishments. In addition to his body of research on sleep, he was my teacher at the University of Chicago. Since he was the only man in America who was studying human sleep when I chose to attend medical school at the University of Chicago, had I made any other choice I would surely have had a very different career. We discovered and described rapid

eye movements during sleep in the early 1950's in Kleitman's laboratory. The nature and function of REM sleep and its relation to dreaming dominated my efforts for at least a decade. My involvement with sleep deprivation was limited to staying up all night in the sleep laboratory, and then falling asleep in class the next day. I was thrown out of several classes by professors who did not understand fatigue any more than many individuals in our society today.

What we didn't know scientifically about sleep deprivation and its role in many aspects of our society in the 1950's would fill a book. In 1958, I was involved in a highly visible wakefulness marathon. A disc jockey was staying awake for 200 hours in a glass booth in Times Square in New York, and claiming he was breaking the world's record for longest duration without sleep. Several investigators from the University of Oklahoma were observing him and carrying out a variety of performance tests. I was, at the time, working in New York. I had developed the technique of continuous all night polysomnography, and I had defined the EEG stages of sleep which allowed them to be quantitatively measured. My task was to record the disc jockey's recovery sleep when the marathon ended. This single recording conclusively revealed the existence of what is now called REM rebound.

Thirty-eight years ago nothing much was known about the psychotropic effect of stimulants. In order to stay awake, the disc jockey took progressively higher doses of methylphenidate (Ritalin). On the last day of the marathon, I believe the dose was up to 300 milligrams. This precipitated a psychotic episode (fortunately very short lasting), but the episode was mistakenly attributed to the sleep loss by the investigators. This seemed to con-

firm stories from the Korean War about sleep deprivation as a form of coercion and its psychological effects, as well as some speculations about the psychological role of the newly discovered organismic state of REM sleep. For my own part, I was diverted for a time from a direct interest in total sleep deprivation by this event and subsequent studies.

Randy Gardner was also mentioned today. He was a high school student who in stayed awake for 240 hours in 1965. His motivation was to establish a new world's record for going without sleep. I was intimately involved in this event, leading a team which carried out observations both during the deprivation period and during the recovery. We were still very naive, and we allowed him to "rest his eyes" much more than we should have. Accordingly, knowing a great deal more today about the occurrence of microsleeps in apparently awake individuals, I'm not so sure Randy Gardner was undergoing total sleep deprivation. However, he did endure an enormous amount of sleep loss, and came through the ordeal with relative ease. We mistakenly thought he was adequately recovered after one sleep period, so that was all we recorded. We now know that it takes longer to repay lost sleep.

Another high school student who lived near Stanford University where I became a member of the faculty in 1963, decided he was going to break Randy Gardner's record by staying awake longer than 240 hours. I was happy to conduct observations as I had done with Mr. Gardner. However, to my great surprise, within two days he "fell off the cliff," to use the expression coined by Dave Dinges in his presentation earlier today. After about 60 hours of wakefulness, the student was crying, sobbing, and begging to be able to go to sleep. There must be huge individual differences in response

to sleep loss which we know almost nothing about.

In 1964, my family and a few friends were having a little picnic dinner in our back yard. We were extremely startled when a car came crashing through the bushes and into our back yard, stopping about 10 feet from where we sat with our guests. The driver, fortunately unhurt, was a Stanford student who was quite drunk and had missed the turn. In those days, they had a student court. I attended the trial, and was furious when the only punishment was a mild reprimand. That's when I learned that our society didn't seem to care very much about drunk driving. But thanks largely to Mothers Against Drunk Drivers (MADD), you have seen an enormous cultural shift in attitude about DUI. It is no longer acceptable.

Shortly thereafter, I served for the first time as an expert witness in a lawsuit involving responsibility for damages as the result of a sleep-related crash. At the trial I was asked the question, "Is someone who falls asleep at the wheel truly responsible?" Amazingly, it was the first time I ever considered that question and it has preoccupied me and my research for the ensuing three decades. In this instance, a driver had unambiguously fallen asleep, and as a result, four people had died. As the driver approached the moment of sleep, was there a point where he was helpless, and could not do anything even if he wanted to? Or, was he simply irresponsible and at fault for deliberately letting it happen?

From 1970 to about 1985 I was enormously preoccupied with getting sleep disorders medicine fully operational, and in establishing the American Sleep Disorders Association. A major landmark for me occurred in 1982 when I became involved in an international project

to study the adequacy of layover sleep of pilots following transoceanic flights sponsored by NASA/Ames (ref). The project was led by Dr. John Lauber who went on to become a member of the National Transportation Safety Board for two terms. His key role on the Board was praised today, and I will join in. John was a wonderful colleague, and from him I learned an enormous amount about the operational community.

In 1988, while I was still Chairman of the Association of Professional Sleep Societies and I asked John to be the keynote speaker at our annual meeting. I hope some of you remember his outstanding presentation about fatigue in transportation. He showed a videotape of the China Airline near disaster, where a Boeing 747 was flying at 41,000 feet, and because of a pilot error, tail spun all the way down to 9,000 feet. The computer simulation of this "incident" was just about as riveting and suspenseful as anything you could possibly imagine.

John really inspired me. So much so that a few weeks later in Washington, DC, Mr. Dale Dirks, Washington representative of the American Sleep Disorders Association, and I persuaded Senator Ted Kennedy, Chair of the Labor and Human Resources Committee, to create the National Commission on Sleep Disorders Research as part of the NIH Reauthorization Act. The delay and jockeying to appoint Commissioners was an unexcelled example of our creaking bureaucracy. By the time the Commission had its first meeting at the end of March two years later, where I was elected Chairman, serious efforts to balance the Federal budget were well underway.

I knew several members of the AIDS Commission, and I knew that they had been supported by an annual budget of \$2 million and a dedicated support staff of ten people. You can therefore imagine how I felt when the Director of NIH came to the first Commission meeting and announced there were no funds. As far as I know, this was the first of what have come to be called "unfunded mandates." It was also a personal moment of truth. On the one hand, it was obviously the opportunity of a lifetime to bring societal issues related to sleep deprivation and sleep disorders onto the front burner. On the other hand, how could the Commission possibly function with no financial support?

I decided finally that I had to do whatever was necessary to take advantage of the opportunity. Fortunately, several individuals from the private sector provided partial funding which enabled us to carry on. One of these was Dr. David Hamburg, President of the Carnegie Corporation, who is one of the men I admire the most on this planet, and has devoted his life to saving it.

When the Commission finally began to operate, the very first Federal document that we received was the NTSB report of the 1989 grounding of the Exxon Valdez. It was a dramatic and compelling example of the catastrophic consequences of fatigue. It was just what we needed to galvanize our work. We also received all the other reports that were mentioned this morning by Jim Danaher, the railroad accidents, the fatal-to-the-driver truck accidents, and the World Prodigy grounding. The early and continuous hook-up with NTSB was extraordinarily important in our work.

At the end of the Commission's task, we had learned and we reported to the Congress that society is plagued by two gigantic, but largely

hidden, problems. The first is the existence of pervasive sleep deprivation in all components of society. The second is the pandemic of undiagnosed and untreated or misdiagnosed and mistreated sleep disorders. Realize if you will, that we knew this in 1991. Of the latter, the most prevalent, as you've heard today, is obstructive sleep apnea. It is also the most serious of the highly prevalent sleep disorders, and as you now know can cause overwhelming fatigue.

Once again, I want to acknowledge the very strong support we have received from the Senior Senator for the State of Oregon, the Honorable Mark Hatfield. In 1990, the Commission was invited to hold a public hearing in Portland and we captured his attention on that occasion. He has been a staunch advocate ever since. He is now Chairman of the Senate Appropriations Committee. When the Commission recommended a Federal focus to deal with the problems of fatigue and sleep disorders, Senator Hatfield introduced the legislation to create the National Center on Sleep Disorders Research. This legislation was later folded into the NIH Reauthorization Bill and signed into law by President Clinton on June 10, 1993. I was very excited because I thought this would be an opportunity to have my picture taken in the White House when the President signed the NIH Reauthorization Bill. I had an acquaintance on the President's staff so I was pretty sure I could get an invitation. This is when I learned things were not optimally organized because nobody knew when the signing ceremony was going to happen. Nobody could tell me. I was supposed to go to Paris for a conference, and I held off as long as I could. Finally I got on the plane, and when we landed, I learned that the signing ceremony was taking place that very day. I was sad, even in Paris.

There was a little amusing byplay surrounding passage of the Bill to create the National Center. In his remarks on the floor, Senator Hatfield opened with a dramatic description of an event in his home state of Oregon where a truck driver had fallen asleep and “wiped out a town.” It was, of course, a very small town, but at 5:00 A.M. a heavy truck didn’t follow the gentle turn of the highway and without turning or braking smashed through the filling station, the grocery store, and came to rest in the tavern. A controversy erupted in the Oregon newspapers because the driver, who was not fatally injured, denied that he had fallen asleep or had been suffering from fatigue. So here was a Senator on one side, and the truck driver on the other. There are now guidelines promulgated by NTSB to deal with this type of accident. I wish we’d had a firm grip on them when this happened, so we could have supported the Senator.

I have already said that this meeting is truly a landmark. Because of that, I decided to spend the day listening very carefully to the speakers and to underscore some of their most important points. I’ve been teaching undergraduates at Stanford since 1963, and I’m always amazed at what they do not remember from my course. When you encounter a student, a year or so later you’re lucky if they remember two or three things. I’m sure you’ll do much, much better than that. But even so, there are some things we hope you will remember and take seriously for the rest of your life.

Here is the first point I want to make very firm and clear. Fatigue is the feeling that accompanies a strong physiological tendency to fall asleep. Most people think it takes a lot of time to fall asleep, but it doesn’t. The actual transition from wake to sleep is virtually instantaneous. Drowsiness is not the first step in the

process, it’s the last step. It is the last event of wakefulness just as we are actually falling asleep.

In 1977, we published a study (ref) that documented the rapid and abrupt nature of the transition from awake to sleep and vice versa. In this study, subjects lying supine with continuous brain wave recordings and with their eyelids taped open were exposed to the brilliant flash of a strobe light situated about six inches above their face. Their task was to press a micro-switch taped to a finger when they saw the flash. The strobe light was programmed to flash irregularly every two to eight seconds. In a typical sequence, the subject would execute a number of responses immediately after each flash of the strobe light. Then, abruptly, we would see a failure to respond. If we immediately asked the subject why he didn’t press the micro-switch, he would invariably say, “The light didn’t flash.” In other words, he did not press the switch in response to a blinding flash that occurred right in front of his open eyes because he didn’t see it! He was completely, functionally blind, whereas several seconds earlier, he saw the flash perfectly well. When we examine the brain wave patterns associated with this response failure, we almost always see a brief (one to several seconds) microsleep. At the moment of sleep, a virtually instantaneous transition, the subject has become completely blind. Subjects usually report a strong wave of drowsiness just before falling asleep. We have done a number of experiments along these lines and it is well established that human beings can progress from wide awake to sleep in literally seconds, maybe even faster. We may conclude that when we feel a strong wave of drowsiness while operating a vehicle, if we do not respond to it immediately, we have placed ourselves and others in extreme jeopardy.

You heard about the Multiple Sleep Latency Test (MSLT) several times during the day. I asked at least 15 people attending this meeting if they were familiar with this procedure. All said no. The MSLT is a standardized method used all over the world for the objective measurement of daytime sleepiness. It has been a very powerful tool in understanding human sleep deprivation, but its great usefulness is inversely proportional to the awareness of it in the transportation industry.

This direct scientific attack on daytime sleepiness would not have come about were it not for the clinical problems we were seeing on a daily basis in the Stanford University Sleep Disorders Clinic, of which I was then Director. Our initial interest was in patients diagnosed as having *narcolepsy*, an illness typified by irresistible attacks of sleep, and in those diagnosed with *obstructive sleep apnea*, a condition of severely disturbed respiration during sleep. Both of these conditions drastically impair daytime alertness. However, when we first began studying these patients, we had no objective way to measure sleepiness.

During the spring of 1976, a group of Stanford students carried out the first MSLT type study of daytime alertness under conditions of total sleep loss. This experiment helped set the ground rules of what would become the standardized form of the test. The students stayed awake for two days, during which time a “sleep latency” measurement was taken every two hours as follows: The student was told to lie quietly in bed, in a darkened room, and to try to fall asleep. As soon as the subject fell asleep, the test was ended—that is, the student was roused—and “sleep latency” was scored according to how many minutes had elapsed (a score of 0 indicating maximum sleepiness; a score of 20 maximum alertness). If the stu-

dent failed to fall asleep within twenty minutes, the test was ended and the student scored 20. With this test design, no sleep time was permitted to accumulate during the experiment, and the subject did not get too bored if unable to fall asleep. (Sleep latency was also measured before the experiment and again after the subject was finally permitted to sleep.)

When Mary Carskadon and I, with our undergraduate technicians, launched the Stanford Summer Sleep Camp, we continued these methods. During ten remarkable summers, we studied sleep patterns and daytime alertness in people of all ages, who spent anywhere from several days to several weeks at the “camp.” In one early study, Stanford University undergraduate volunteers, given the MSLT on each of several consecutive days, were found to be pathologically sleepy (their sleep latencies were below five minutes) even though they were spending their “normal” eight hours in bed. When their time in bed was extended to ten hours (with about 9 1/2 hours of actual sleep), their daytime alertness progressively improved. The cause of the severe sleepiness in the undergraduates was obvious: *They were simply not getting enough sleep.* Meanwhile, we were finding that 10-, 11-, and 12-year-old children who routinely spent ten hours in bed at night had optimal physiological and subjective alertness in the daytime.

Some people think you can **learn** to fall asleep quickly even if you are not sleep deprived. This is wrong. Children who are prepubertal, the 10, 11 and 12 year olds, sleep 9 1/2 to 10 hours at night and they are not the least bit sleepy all day long. Nothing can cause them to fall asleep. Boredom ? No. Warm room? No. Heavy meal? No. None of these things decreases the daytime alertness of children who have no sleep debt at all.

In what I regard as our most important sleep camp study, we partially sleep-deprived ten young adults for seven consecutive nights, allowing them just five hours sleep per night. Over the seven-day period, with the same amount of sleep each night, their daytime alertness progressively *worsened*—a result that has been confirmed numerous times by other investigators. This was the first study strongly suggesting that all lost sleep accumulates as a debt.

The issue and concept of sleep debt came up many times today. Sleep debt is real. It's been elusive in the past, but today I think the scientific evidence for its existence is incontrovertible. In other words, there is a "sleep debt" that accumulates just like any credit account. The brain keeps very accurate figures on the accruing sleep deficit, which drives the tendency of the brain to fall asleep. My first use of the term, however, was in testimony to the House Appropriations Committee. I was trying to shock them into paying some attention by saying that the National sleep debt was more serious than the monetary debt. I had a poster that I showed with the sleep debt mounting up to ever more dangerous levels.

Several groups of investigators, using the MSLT, have found severe physiological sleepiness to be pervasive in communities and in workplace environments. You might expect more people to complain of general fatigue. But people have a strange inability to perceive their sleepiness accurately. Dr. Thomas Roth and his colleagues at Henry Ford Hospital Sleep Disorders Center (one of the most outstanding) in Detroit reported in 1988 on a study of a large sample of young adults. The subjects were recruited specifically because of their claims that they were *not* bothered by daytime sleepiness or any other health prob-

lem. Yet when their daytime alertness was evaluated after eight hours in bed, *34 percent tested pathologically sleepy!* Only about 10 percent of those who claimed to be feeling fine were in fact optimally alert. Almost certainly, if we studied only individuals who actually *admitted* to experiencing daytime sleepiness, a much higher percentage would exhibit sleepiness at the pathological level.

While sleep/wake issues affect myriad public-policy areas, there is an unfortunate tendency for uninformed policy makers to suggest that it is "normal" to be sleepy. To test this, Dr. Roth and his colleagues selected a group of their sleepest subjects and persuaded them to spend ten hours in bed for six consecutive nights. Just as we had found in the Stanford Summer Sleep Camp, ten hours of sleep improved their daytime alertness significantly. Furthermore, their cognitive performance also improved! Thus, the intellectual capacity of these sleepy individuals, was significantly impaired. If feeling this way is the "norm," then we are unquestionably a sleep-deprived and sub-optimal society. Nearly all of us need more sleep than we get.

Every hour of sleep less than his or her needed amount is carefully registered by the brain as a debt, and this debt is precisely tabulated over time. It is quite possible that the debt includes an hour lost a month ago or a week ago as well as last night. Obviously, this assumes that there is a specific amount of nightly sleep for each individual which will maintain the same degree of daytime physiological alertness over time. It also assumes that this amount varies somewhat from individual to individual.

In an individual who needs nine hours a night, and who sleeps six hours a night for a week, the lost sleep would add up to a debt of 21 hours

by the end of the week. This sleep debt drives the tendency of the brain to fall asleep, and the amount of the debt, **not** the feeling of sleepiness, determines the level of risk that any person operating hazardous equipment or making crucial decisions may make a disastrous error. Persons who are very sleepy in the daytime even though they are sleeping around eight hours at night and do not have a specific sleep disorder can reduce the problem by increasing their daily amount of sleep. This is usually done by increasing the time in bed.

Two similar experiments done more than twenty years apart dramatically confirm the concept that human beings can unknowingly carry a large sleep debt. Neither experiment was designed by the researchers primarily to study sleep. In both experiments, brain waves were recorded continuously as one of many measurements of the effects of the experimental protocol on the human volunteers.

The first experiment was carried out over twenty-five years ago at the U.S. Naval Hospital in Bethesda, Maryland, as a test of sensory deprivation. At that time, it was hypothesized that a substantial reduction of sensory input would dramatically impair normal mental processes, and that disorientation, hallucinations, and even psychosis, might be the consequence. Subjects were required to remain in a cubicle, where they were isolated from light, sound, and interactions with the outside world. The temperature was held constant, neither perceptibly cool, nor perceptively warm, and the subjects wore gloves to minimize tactile sensations. Brain's waves were recorded continuously 24 hours a day by means of very thin wires that were looped through the subjects scalp so they did not have to be replaced. Subjects remained in this sensory deprivation situation for one week.

Having absolutely nothing to do, subjects generally slept a great deal throughout the first twenty four hour period. The mean total sleep time for the group was above 16 hours on the first day. However, the mean total sleep time declined on each successive day, and on the last (seventh) 24 hour period, the group mean was close to eight hours.

This experiment might be viewed as a test of the old theory that sensory bombardment of the brain was necessary to maintain wakefulness. If so, it would be an extremely negative result, because with a tremendous reduction in sensory input, sleep time did not remain high. The subjects in this experiment were young naval personnel. Since we now believe that nearly all young people are chronically sleep deprived, it may be assumed that even if the subjects had maintained reasonably normal schedules prior to the experiment, they would have begun the sensory deprivation protocol carrying a substantial sleep debt. We may assume that this sleep debt powered an enormous increase in total sleep time when there was essentially nothing else to do all day long. However, as the sleep debt was progressively reduced, the sleep drive progressively weakened and the daily amount of sleep decreased accordingly. Even with absolutely nothing else to do all day long, the subjects were unable to sleep more than eight hours.

The second experiment, also mentioned today by one of the presenters, was carried out by Dr. Thomas Wehr and his colleagues at the National Institutes of Health. Its purpose was to examine the effect of different photo periods (duration of time spent in the light, as opposed to in the dark) on human mood and function. The experiment was carried out in a laboratory setting with continuous recording of sleep parameters while subjects were in bed in the

dark. Each subject slept in the laboratory 24 hours a day, seven days a week for five consecutive weeks.

During the first seven days, the photo period during which subjects were out of bed in the light was the conventional 16 hours, and each day they spent the same eight hours in bed in the dark. After one week, the photo period was changed to ten hours during which the subject were out of bed in the light; and they were required to be in bed, in the dark, for the same fourteen hours each day over the course of 28 consecutive days. During the five week period, the subjects were administered daily mood scales and a variety of other tests.

During the first week, or baseline period, the mean nightly sleep time for the subjects was 7.6 hours. When the subjects were switched to the ten hour photo period followed by fourteen hours in bed, in the dark, their total sleep times jumped to nightly amounts above twelve hours on the first day and then gradually declined. In the fourth week of the ten hour photo period schedule, total sleep time for the group had leveled off to about eight hours and fifteen minutes each day even though the opportunity to sleep remained at fourteen hours.

The interpretation of these results is that the subjects entered the protocol carrying large individual sleep debts. Of course, neither the subjects nor the researchers were aware of such a possibility. The baseline period certainly did little to reduce the subjects' sleep debts, and may even have resulted in a small increase. When the opportunity to sleep was greatly increased, the large sleep debt, in the same manner as in the first experiment, powered a very large increase in total daily sleep time. As the sleep debt decreased, total sleep time per day declined proportionally. If we assume that the

"steady state" value in the last week of the ten hour photo period represented the actual daily sleep need for this group of subjects, we may conclude that all daily amounts above these values represented "extra" or "make-up" sleep. Accordingly, the mean reduction or "pay back" of the sleep debt averaged about thirty hours. If subjects were not at all sleep deprived, they would have to spend more than three consecutive days with no sleep at all to accumulate a sleep debt of similar magnitude. Another very notable result of this experiment was the dramatic improvement in the subjects' mood, sense of well being, and energy level as indicated by various tests.

These experiments demonstrate that individuals who are getting what society would deem to be normal amounts of sleep, can, at the same time, be carrying a large accumulated sleep indebtedness. How long such an indebtedness would persist if no extra sleep were obtained is not known. However, it is obvious from the second experiment that to be able to sleep thirty extra hours, and to have accumulated such a debt in small increments means that sleep indebtedness must persist for substantial amounts of time-- weeks or months at the very least. In addition, this experiment, and others like it, present evidence that a large sleep debt impairs our mood, our sense of well being, our energy, and our intellectual function. This means that the negative consequences of chronic sleep deprivation are not confined to having microsleeps at critical moments. There is also a general and unrecognized global impairment. Finally, it is reasonable to hypothesize that a major improvement in our function could be achieved by reducing our sleep indebtedness to a very low level.

All we hear about today is balancing the budget and cutting all sorts of government programs. However, in my opinion, it is the "National Sleep Debt" that we should be worried about, and the newly Republican Congress should have an equal fervor for doing something about this problem. In 1995, there was a dramatic footnote to "America's largest oil spill," the aforementioned grounding of the giant tanker, Exxon Valdez. In civil trial, the jury awarded the plaintiffs five billion dollars in damages. Thus, a single sleepy person cost his company in excess of seven billion dollars, together with an untold loss of goodwill. And companies still have not taken this problem seriously on a large scale.

The pervasiveness of sleep deprivation is even more clear today than it was during the 1990-91 study of the National Commission on Sleep Disorders Research. Moreover, we are sure that crashes caused by falling asleep at the wheel are vastly underreported. Many states do not even have a category for "fatigue" as a cause of an accident. Accordingly, we have the grotesque situation that there is no cause of death when people fall asleep at the wheel.

An accident occurred recently, practically in my back yard, which dramatically emphasized the inadequacy of investigation and reporting. A two lane highway runs by my house. It is straight for a long distance and then there is a gentle curve. Recently, a car traveling approximately 50-60 mph according to witnesses, approached the curve and without braking or changing direction drove straight into a tree. Hearing the ambulance and police car so near by, I ran to the scene to see what had happened. The driver was dead and he was subsequently found to be free of drugs or alcohol. He looked to be about 30 years old making a heart attack highly unlikely. I asked the investigating of-

ficer if he was going to try to find out how long the victim had been driving prior to the accident, or perhaps ask a family member about his schedule during the previous week, and whether or not he was a loud snorer. At a certain point, the investigating officer became irritated with me and asked me to leave him alone while at the same time suggestively patting his handcuffs. The next day in the paper, he was quoted as saying, "The car had veered off the road and the cause of the accident was unknown." This is actually exactly the type of accident where the National Transportation Safety Board would follow up with an investigation of the victim's schedule, and, if appropriate, would identify fatigue as the cause.

Now, you immediately ask the question, "Why aren't we aware of these huge loads we are carrying?" The main reason is another process that has also been mentioned today, the circadian process, which causes a period of strong alertness at the same time each day. When the Multiple Sleep Latency Test is extended into the evening hours we always see a marked improvement in alertness, or a lengthening of sleep latency, with no sleep at all. This is what we at Stanford call "clock dependent alerting." There is a misattribution of this process particularly by young people who experience this alerting in the evening, that yes, I'm fatigued, I'm tired, I'm sleepy, but the fatigue disappears. It dissipates. It goes away. I feel great in the evening. If any of you teach undergraduates and are involved with them, you know they are vivacious and energetic in the evening even though they were groggy and falling asleep in class in the day time. But they don't understand that when this alerting affect passes, they are even more vulnerable to the likelihood of falling asleep. This is when they are driving home from parties and other evening activities.

Another point to emphasize was discussed by Dr. Roth today. I think it is one of the most important findings in this whole area. Sleep deprivation dramatically potentiates the sedative effect of alcohol. I just talked with Pat Waller, the Director of the University of Michigan Transportation Research Institute. She said that one of their big research issues is the very low alcohol levels in the blood of young people who have had fatal accidents. They feel such low levels should not be causing accidents. However, the real culprit in many crashes "caused" by alcohol is sleep deprivation.

The possibility was raised today that people who work in hazardous situations should be screened for obstructive sleep apnea. The National Commission carried out a study of truck drivers. We found a shockingly high prevalence of sleep apnea in overnight tests (ref). We also found several drivers who were severely ill. One driver kept falling asleep on the chair while we were trying to hook him up. We were allowed to send him a letter. In retrospect, I was ashamed that I'd walked away from that.

Now, we're here in Tysons Corners to do something, and I think a very important part of this meeting will be tomorrow. I wanted to just make a few suggestions. We must assume fatigue in all accidents. We must investigate all accidents using the NTSB guidelines. In a recent accident that occurred in White Plains, New York, a propane truck drifted out of its lane, crashed into the concrete support of an overpass, and exploded. It was a horrible accident. The driver was killed instantly. Headlines the next day in the New York Times read "alcohol and drugs didn't cause the crash, what did?" So apparently the authorities, or at least the journalists who were there, were clueless about the facts of fatigue and its role in crashes.

The effort to enhance awareness about fatigue and sleep disorders should be totally cooperative. Such efforts could be enormously multiplied with the participation of all of the operational communities at this meeting. We should ask not just our companies and our industries, but our entire communities, "Are we educating everyone about fatigue?" Is this knowledge going to grade school children and truck drivers? Is it going to middle school children and airline pilots? Above all, is it going to high school students and others who are learning to drive? Are any of the state colleges teaching this material? What about graduate programs? How can we tolerate the absence of teaching about sleep deprivation and sleep disorders in our medical schools? I say to you today, this group is an island of awareness in a vast sea of ignorance. "American society," to quote Senator Hatfield, "is a vast reservoir of ignorance." You can fill the reservoir with knowledge. You can make a difference.



THE AVIATION WORKING GROUP #1



Moderator Dr. Barry Strauch, National Transportation Safety Board

Analyst Dr. Ben Berman, National Transportation Safety Board

Technical Representatives

Mr. Bob MacIntosh, National Transportation Safety Board

Mr. David Schroeder, Federal Aviation Administration

Hours of Service and Scheduling

The group expressed the view that, because of the criticality of scheduling on human fatigue and alertness, that duty time limits should be upgraded for flightcrew members and established for flight attendants, as well as address issues of circadian rhythms and human performance. All proposed rule changes should be based on the results of scientifically sound sleep research. In addition, it was suggested that rules be promulgated to establish controlled rest during long-haul flight operations.

Nevertheless, concerns were raised that revised flight and duty time rules not be so rigid as to create their own safety hazards. For example, an issue in the Tenerife ground collision between KLM and Pan American Boeing 747s was the inflexible flight and duty time restriction the KLM flightcrew faced at the end of the scheduled flight to Amsterdam. One suggestion was to pattern rules after the advanced qualification program (AQP), which provide airlines considerable flexibility to tailor pilot training to their own needs and circumstances, while maintaining a high degree of FAA oversight. Finally, some attendees expressed concern that proposed rules not place United States

aviation interests in the global economy in jeopardy against those of nations that have less restrictive rules and regulations in place.

Personal and Technological Countermeasures

Many innovative proposals were offered during the session. For example, one attendee suggested that airlines and flightcrews work together to obtain “circadian friendly” hotel rooms in which quiet corridors would be maintained, blackout curtains hung in the rooms, and other measures implemented to enhance rest during those periods when most people are active. An additional proposal called for using FOQA (flight operations quality assurance) data to match pilot performance against flight schedule and other data that have been associated with fatigue. Also, expert systems could be used that, with existing data on sleep, help pilots bid schedules, and airlines employ pilot bids, that could minimize the emergence of fatigue during subsequent flight operations. Similarly, a proposal was offered to employ automatic devices in cockpits that would alert crewmembers or require crewmember responses during a flight, to assure that pilots would remain alert during a long flight.



Education and Training

Attendees suggested that education for all personnel was critical to the effectiveness of countermeasures. Further, the group believed that successful countermeasures against fatigue require the active participation of all corporate levels, executive/managerial as well as those directly involved in flight operations. Attendees expressed the view that, following the conclusion of the conferences, the NTSB and NASA inform airline executives directly of the results of the Symposium to help obtain their cooperation in reducing the effects of fatigue at their airline. In addition, basic guidelines should be provided to airlines to assist their management in implementing fatigue countermeasures program at their airline.

Some attendees, representing general aviation interests, also raised the issue of educating general aviation pilots and corporate aviation departments in the need for effective fatigue countermeasures.

SUMMARY VIEWGRAPH

Scheduling

- Upgrade Flight/Duty/Rest (F/D/R) rules
- Regulate, not negotiate, F/D/R rules
- Apply science to F/D/R rules
- Finalize rule on F/D/R
- Avoid rigidity in F/D/R rules
- Level the F/D/R playing field world wide

Countermeasures

- Sleeping quarters at duty site and “circadian-friendly” hotel rooms
- Correlate flight data recorder readouts with crew fatigue factors
- Expert systems to help managers design crew schedules and help pilots bid schedules
- Educate top managers
- Cockpit crew alertness monitoring devices

Education

- Educate personal countermeasures, and educate the family
- Big and small airlines need basic guidelines
- Top-level buy-in is essential
- Integrate personal and company countermeasures
- Don't forget general aviation



THE AVIATION WORKING GROUP #2



Moderator Mr. Jim Danaher, National Transportation Safety Board

Analyst Dr. Malcolm Brenner, National Transportation Safety Board

Technical Representatives

Mr. Bob Benzon, National Transportation Safety Board

Mr. Ronald Simmons, Federal Aviation Administration

Hours of Service and Scheduling

The Aviation Group 2 felt that government regulation of flight and duty time standards was the starting point and foundation for all activities at controlling fatigue in operations. These regulations set the minimum standards for operations beyond which personal and company countermeasures can be applied. The group felt that it was important that the regulations provided core guidelines but also captured important differences in the industry, especially, for example, by providing special provisions applicable to overnight operations. The group felt that “rest” should be defined more operationally than the present definition as the number of hours off-duty. That is, “off duty” time rarely equals “rest” time. It is necessary to allow time for commuting, personal hygiene, and sustenance. Fatigue issues should be addressed more actively in accident and incident reports by the NTSB and the FAA. Fatigue should be assumed to be present until the investigation can rule it out.

Personal and Technological Countermeasures

The group felt that technology was a support, but not a substitute for personal management. Industry and individuals both have responsibilities for minimizing fatigue in operations. Industry can help by developing procedures so pilots can report themselves “too fatigued” to work without punishment, and by providing rest accommodations for quality sleep without noise interruptions. Employees can help by arriving at work rested, arranging their commutes from home and activities during the off-duty time so they are properly rested. When technology is developed, it should not be used to erode other existing or future fatigue countermeasures based on scheduling or personal management.

Education and Training

The group felt that there should be a clearing house to collect and make available successful training materials on fatigue developed by different transportation modes, different disciplines, and different nations. Education is the

most basic countermeasure for fatigue. It should be provided to managers, schedulers, and the general public to change attitudes and recognize the importance of fatigue. Pocket checklists, and checklists integrated into normal operations should address fatigue issues in heightening awareness of the fatigue-producing aspects of duty periods and in judging personal fitness for flight. ASRS reporting forms should enhance their reporting of fatigue, and NTSB/FAA investigations should enhance their monitoring of fatigue issues. Fatigue should be examined on the part of pilots, air traffic controllers, mechanics, and all other personnel in the operational system.

SUMMARY VIEWGRAPH

Scheduling

- ➔ Overnight flying – special regulations
- ➔ Address fatigue in mishaps
- ➔ Government regulation essential
- ➔ Define “rest” more operationally

Countermeasures

- ➔ Technology supportive of personal management
- ➔ Industry support of individual management and decisionmaking – industry support systems and “too fatigued”

- ➔ De-link technology and punitive actions
- ➔ Balance between industry/individual responsibility – commutes, rest accommodations, and rest periods

Education

- ➔ Intermodal, international, interdisciplinary training clearinghouse
- ➔ Managers, schedulers, and the public need education
- ➔ Fatigue-related work schedule guidelines
- ➔ Enhance ASRS, NTSB, and FAA monitoring of fatigue



THE RAIL WORKING GROUP



Moderator Mr. Bruce A. Magladry, National Transportation Safety Board

Analyst Mr. David Mayer, National Transportation Safety Board

Technical Representatives

Mr. Robert Lauby, National Transportation Safety Board

Mr. Garold Thomas, Federal Railroad Administration

Hours of Service and Scheduling

The lack of schedule predictability and regularity were identified by the group as the number one fatigue producing problems for both train crews and management. For, without timely, accurate schedule information, railroad employees cannot effectively manage their off-duty time to minimize fatigue. The scheduling difficulties that give rise to unpredictability and irregularity are derived from several interrelated, but often conflicting demands that the railroads themselves cannot fully control. Factors that impact scheduling include: equipment breakdowns, emergencies, and power failures, imbalances in the direction of traffic flow, and the demands of customers who have increasingly moved to just-in-time pick-up and delivery. Pool dispatch, extra board scheduling, and deadheading of crews also contribute to the problem.

Exacerbating scheduling difficulties is the Hours of Service (HOS) Act developed in 1907. It was not based on science and does not necessarily permit sufficient continuous sleep periods nor does it incorporate modern knowledge of circadian rhythms. Historically, it has also promoted an adversarial relationship between labor and management. The group felt it no longer works well. In a spirit of cooperation, government, management and

labor should seek innovative and flexible schedule solutions and HOS reforms through pilot projects. However, as a basic tenet of railroad operations, the HOS should not be changed without a firm scientific basis and careful review by all the affected parties.

Personal and Technological Countermeasures

Currently employed fatigue countermeasures are not adequate. Alerters, for example, can be complied with while an employee is severely fatigued. Some existing crew quarters, intended to facilitate rest away from home, are not adequate for daytime sleeping because of noise or lighting or even maid service. Another countermeasure, albeit an unauthorized one, napping, can actually bring on disciplinary action. Nevertheless, there are times when it could be safely and effectively used to reduce fatigue and improve alertness. The group felt appropriate napping should be legitimized.

Group members felt some conditions and procedures seemed to induce fatigue, like poor locomotive cab environments and boring tasks. It was suggested crew input could improve both cab and task design. It was also suggested that various communications equipment and methods should be explored to give employees the

most up to date and valid line-up information so that they plan their sleep accordingly in order to report to work well rested. However, when significant line-up changes occur and an employee is called to duty early without having slept, there should be a mechanism to allow him to mark off without penalty. To do otherwise, may force a fatigued employee to work and create a danger to himself, his railroad and the public.

Fitness for duty testing was also addressed. It was felt that current tests are not yet valid and reliable, and that they miss the point anyway. Efforts should be directed toward developing schedules and working conditions that prevent fatigued employees rather than keeping the current conditions in place and trying to detect fatigued employees. Finally, responsibility for developing and promoting effective countermeasures was believed to belong to all affected parties.

Education and Training

Addressing fatigue through education and training was deemed essential and was considered a win-win proposition for labor and management, improving safety and productivity for each. The group felt that employees should receive training about sleep, sleep disorders, sleep strategies, and fatigue countermeasures. Both labor and management employees should receive the training in order to provide a common understanding of the issue. The training should be based on science with practical solutions, but should not ignore the important components of personal responsibility and behavioral change. Follow-up and feedback were also considered essential to determine efficacy and to reinvigorate individual efforts.

Several railroads already have fatigue education programs in place. The group acknowledged the value of such programs if they do not stand alone. They should be part of a multifaceted approach designed to manage fatigue and promote alertness. Training must accompany other efforts from labor and management to alter operations to facilitate individual employee actions to alleviate fatigue. Thought should also be given for protection of the jobs of employees who come forward after recognizing they have a sleep disorder.

SUMMARY VIEWGRAPH

Scheduling

- Schedule predictability and regularity
- Hours of service flexibility; Minimize deadheading and overnights
- Hours of service provisions based on science and modern demands
- Railroads should conduct hours of service pilot projects
- Enhanced trust to promote innovative thinking

Countermeasures

What is needed:

- Crew quarters suited for sleep
- Crewmembers should be able to mark off when fatigued without penalty
- Tasks that minimize boredom

- Legitimize sensible crew napping
- Fitness for duty testing -- not yet valid or reliable and misses the point
- Improved cab design using input from locomotive crews

Education

- Addressing fatigue is a win-win situation
- Education and training is essential – not a stand alone component
- All labor and management should receive training
- Training must be based on science with practical solutions
- Follow-up and feedback are essential
- Job protection for those who seek treatment



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Hours of Service and Scheduling

There is more than enough research today to begin to effect changes in the scheduling practices of the trucking industry. The hours-of-service regulations are 50 years old and need to be changed. They do not fit with the circadian clock. The trucking industry is behind other modes in making changes to the hours-of-service regulations and scheduling practices based upon current research knowledge. The industry can initiate changes separately from federal regulation. The changes cannot be done in a vacuum and need to consider employee, shipper and customer needs. There is also a need to address the problem across the industry and consider the differences between large and small companies. Some of the implications for public policy include the shortage of parking and driver safety at rest stops.

The solutions include regulatory and performance-based measures.

- Revise the hours-of-service regulations
- Increase the number of driver rest areas

- Consider large versus small companies
- Develop performance-based measures

Personal and Technological Countermeasures

Personal and technological countermeasures should be explored and implemented on parallel tracks. Technology includes fitness-for-duty and alerting methods. Fitness-for-duty technologies are about three years away; alerting method technologies are five-ten years away. Personal countermeasures include napping, education, and medical fitness. They can be implemented immediately.

New technologies must be cost effective, show a safety benefit, and maintain the current level of productiveness. There was some concern expressed that fitness-for-duty detection would give drivers a false sense of security and they would thus be more likely to drive drowsy. Consideration to inter-individual differences needs to be considered along with how the fitness-for-duty testing device would be used. Is it for the driver, the employer, or the regulator? There was agreement that there should be penalties for failing a fitness-for-duty test.

Education and Training

Society needs to undergo major attitudinal changes towards driving when fatigued, similar to that experienced with drunk driving. Some promising efforts have been made in the area of education, such as the Wake UP brochure developed by the AAA Foundation and the American Trucking Associations. There is a need to evaluate the effectiveness of these educational materials to determine if they actually change behavior.

Training for management and drivers is not widespread. ATA Safety Management Council is developing a best practices manual to help educate drivers on how to prepare for work.

- Enforcement training is needed for inspectors and police officers.

SUMMARY VIEWGRAPH

Scheduling

- Revise hours of service regulations
- Increase driver rest areas
- Consider small vs. large companies
- Also performance based measures

Countermeasures

- Technology -- there is none -- it is five-ten years away
- Personal -- napping, medical screening, adequate sleep

Education

- Major cultural change toward fatigue needed -- like drunk driving
- Promising efforts toward general education have been made
- Specific training for drivers and management have been less widespread
- Enforcement training is needed



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The working group consisted of more than 80 representatives from various sectors of the maritime industry. Their affiliations reflected the breadth and diversity of the industry. Shoreside managers and shipboard personnel represented many shipping companies in the inland towing, coastwise, and oceangoing trades. Other attendees came from six maritime schools, seven pilots' associations, and a variety of government agencies.

The group's task was to discuss three topics on managing fatigue in the marine industry: Hours of Service & Scheduling, Personal & Technological Countermeasures, and Education & Training. Discussions of each topic addressed three questions concerning implementation: What is currently used, what is needed, and who is responsible? Highlights of the discussions follow.

Hours of Service and Scheduling

Most mariners stand two- or three-section watches when at sea and so they have multiple work periods in a day. The group felt that although the watch system satisfies current hours-of-service regulations, problems of sleep fragmentation and sleep deprivation can arise. The group noted that the potential for long-term

fatigue must also be considered--crew members may sign contracts of 10-12 months duration when sailing on foreign flag vessels. Some members of the group observed that an important issue underlying fatigue is workload. In turn, workload is correlated with manning levels. The group felt that there is a need to conduct shipboard workload assessments before regulators consider changes to hours-of-service or to manning regulations. The group concluded that industry should take the lead, in coordination with the regulators, to initiate such workload assessments.

Personal and Technological Countermeasures

Several of the attendees reported that their companies had implemented a variety of fatigue countermeasures. The countermeasures do not have to be "hi tech" to be effective. Even little things like having decaffeinated coffee available near the end of the watch can facilitate sleep during the off-duty period. As another example, some companies had installed acoustic insulation in berthing spaces or relocated those spaces to provide a more restful sleeping environment. Other companies had delegated certain tasks to ratings so as to relieve the workload of the licensed officers. The group



determined that a continued effort was needed to promote both corporate and personal alertness management strategies. They felt that additional interdisciplinary meetings, similar to this Symposium, would be useful for exchanging ideas and experiences with successful fatigue countermeasures. The participants concluded that it is the industry's responsibility to take the initiative in this area.

Education and Training

Currently, there is only a modest amount of education being conducted on fatigue and fatigue countermeasures. The attendees agreed that more education was needed and several of the maritime educators in attendance reported that their institutions were developing courses or course modules on the physiological basis, consequences, and ways of managing fatigue. The group felt that the first and foremost need was to shift the mariners' cultural attitudes concerning fatigue--to dispel the "iron-man" myth that fatigue can be overcome by increased motivation and experience. The group concluded that the greatest likelihood of success for developing and disseminating education was to forge a partnership triangle among management, labor, and government.

Countermeasures

- Some countermeasures are being used in the industry
- Continued effort
- Industry initiatives

Education

- Training and education is available
- Shift culture
- Partnership triangle



SUMMARY VIEWGRAPH

Scheduling

- Duration of the tour
- Review manning
- Industry led initiatives

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Three distinct topical areas were discussed at the Fatigue Symposium addressing fatigue in the pipeline industry: hours of service and scheduling; personal and technological countermeasures; and education. A summary of the pipeline group discussion follows.

Hours of Service and Scheduling

In the area of hours of service and scheduling, it was determined that there currently are neither Federal or State standards nor are there any industry guidelines or recommended practices. Therefore, there are great differences in scheduling from company to company. Some general observations were that many employees in the industry rely on unscheduled overtime; in many companies employees have significant input into the schedules that they work; and that most schedules are rotating with 12 hour shifts. Most employees have little idea of the effects of fatigue and there is very little technical information available specific to the pipeline industry.

It was the group's conclusion that there is a definite need for information and guidance on fatigue/alertness issues. It also was concluded

that there is a need for all levels (senior management, supervisors and employees) to learn about fatigue concerns. It was noted that there are industry associations such as the American Gas Association, American Petroleum Institute, the Institute of Gas Technology, and others that could address fatigue concerns and proper interventions in the area of hours of service and scheduling for the industries.

Personal and Technological Countermeasures

Presently, fatigue has not been considered as a problem by much of this industry, therefore, there has been little focus on personal or technological countermeasures. However, the industry does use a number of interventions that have been successful in mitigating some fatigue concerns such as; 2-hour call-ins to remote locations, deadman alarms, video cameras, bright lights and temperature control in control rooms. These interventions were not developed specific to fatigue concerns. The participants agreed that a "napping strategy" could possibly be a useful countermeasure, however, considerable education and understanding by senior management and supervisors of this fatigue countermeasure would be necessary.

There are no fitness for duty countermeasures in this industry with the exception of the liquified natural gas industry where Federal standards require a self-reporting system that the person leaving a shift must state that the person coming on duty is fit to work. The participants concluded that personal countermeasures could be addressed by company employee assistance programs.

Education and Training

Education on fatigue issues is scant. There is some abstract concern about fatigue by senior management and supervisors, however, that concern is not necessarily directed to operational concerns. In other words, most concern over fatigue involves emergency response conditions not day-to-day operations and shift work. The participants agreed that educational programs for senior management, supervisors and employees on fatigue/alertness issues could be conducted for employees first through company employee assistance programs and then to families, if employees saw the merit. It also was agreed that if fatigue countermeasures were marketed as a performance enhancement tool, perhaps senior management would support fatigue safety improvements such as scheduling strategies. The participants indicated there is a need for data on the relationship of fatigue and productivity in order to sell this initiative as an opportunity to top management. There was interest in tailoring the NASA/ Ames program on fatigue to make it more specific to the pipeline industry.

SUMMARY VIEWGRAPH

Scheduling

- Employee reliance on unscheduled overtime
- Employees have significant input into schedules
- All schedules are rotating
- Currently there are no guidelines
- Need information and guidance on fatigue
- Need for more awareness by all

Countermeasures

- Use techniques for monitoring
- Bright lights and temperature control- these techniques are not specific to fatigue
- Napping strategy may work with education
- No fitness for duty countermeasures
- EAP address seminar on fatigue

Education

- Abstract concern about fatigue
- Some knowledge not very detailed

- Need for programs on expectations and fatigue
- Performance enhancement tool – scheduling strategy
- Data relationship fatigue-productivity
- Work smart - Play smart



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